

## DESCRIPTION

PROTEIN SUSTAINING UNDIFFERENTIATED STEM CELLS

5

## TECHNICAL FIELD

The present invention is related to an agent for controlling life or death of a stem cell. More specifically, it relates to a protein suppressing the process for death of a hematopoietic stem cell, and controlling the mechanism for promoting the process for life.

## BACKGROUND ART

15 Treatment of diseases by regenerative medicine has recently been receiving interest. However, such regenerative medicine is not completed so that it is routinely used for a number of patients having organ or tissue dysfunction. To date, in order to treat such patients, organ transplantation as well as assistance systems with medical devices are used for only a few patients with such disorders. However, these treatments have problems such as donor shortage, immunological rejection, infection, lifetime or the like. Particularly, 25 donor shortage is a serious problem, and in the case of bone marrow transplantation, it is difficult to provide a limited amount of samples to a number of patients, even if bone marrow banks or umbilical cord blood banks have been developed. Accordingly, demands have been increasing for regenerative medicine such as stem cell 30 therapy and the applications thereof in order to overcome these problems.



As used herein, "regenerative" refers to the phenomenon where an injured tissue or organ is recovered to its original state, and can interchangeably be referred to as pathological regeneration. The body of a living organism may lose a part of an organ or receive a heavy injury by trauma or diseases during the life thereof. In such a case, whether or not such an injured organ can be regenerated depends on the type of such an organ (or animal species). Regenerative medicine is a medicine which attempts to regenerate an organ (or tissue) not capable of naturally regenerating by itself, and to recover the function thereof. Whether or not a tissue is regenerated can be determined by monitoring the improvement of the function thereof. A mammal has some power to regenerate a tissue or organ to some extent (e.g. regeneration of the skin, liver and blood). However, organs such as the heart, lung, brain and the like has little regenerative power, and it has been considered that once such organs have been injured, they cannot regenerate by themselves. Accordingly, to date, there is no effective treatment except for organ transplantation when an organ receives such an injury.

It has been speculated that organs with high regenerative power contain stem cells. This idea has been demonstrated to be true by experimental bone marrow transplantation using animal models. Further, subsequent studies have shown that such stem cells in the bone marrow are the source for all blood cell regeneration. Stem cells have been shown to be present in organs with high regenerative power such as bone marrow, skin and the like. Further, it has also been shown that stem cells exist even in the brain which has long been



considered to be non-regenerative. That is, all the organs in the body have stem cells, and it has been shown that such stem cells play a role in controlling regeneration of each organ. Further, stem cells present in  
5 each tissue has more plasticity than expected, and it is indicated that stem cells in one organ can be used for regeneration of the other organ.

There is the possibility that stem cells can be  
10 used for regeneration of an organ which to date cannot be regenerated. Therefore regenerative medicine such as stem cell therapy is increasingly more interesting. Recently, the need for the study of regeneration in the medical fields has increased therefore findings on stem  
15 cells or organogenesis are increasing. For example, establishment of embryonic stem (ES) cells having totipotency and the production of a cloned individual from an adult somatic cell are gaining more and more interest. This is because technology regarding development and  
20 regeneration can be used for stem cell therapy. Regenerative medicine using stem cells are in the process of clinical application in each field. There are some fields which have already practiced such regenerative medicine.

25

The origin of regenerative medicine is the presence of reconstructive biology. Reconstructive biology is originated when Wilson demonstrated that separated sea sponge cells processed by pipetting and remixing  
30 formed an individual in 1907 (Wilson, H. V., J. Exp. Zool. 5: 245-248, 1907). With respect to tissue reconstruction in higher biological organisms, amphibian embryo reconstitution was documented by Townes and Holt-



freter in 1955. They found that amphibian embryo treated with dilute alkali solution and then by mixing separated cells a reconstituted organism was formed. Thereafter, a number of trials have been challenged for such reconstitution, however, no significant development has been noted until 1980's.

Regenerative medicine was first generally acknowledged when it was applied to burn injuries. In 1981, Bell produced artificial skin and applied it to the therapy of burn injuries (Bell, E. et al. Science, 211: 1052-54, 1981). Bell, E. et al., embedded skin fibroblast cells within a collagen gel, and cultured epidermal cells in the surface thereof to produce an artificial skin. Here, the idea to reconstruct an organ in a three-dimensional manner using cells and extracellular matrices as material was noted.

In regenerative medicine, it is most important to reconstruct organs. There are roughly two methods for reconstructing organs: organs are reconstructed *ex vivo*; and organs are reconstructed *in vivo*. In either case, stem cells are required for reconstruction of organs. Pluripotency and self-replication ability are importantly required for stem cells used in the above-described application.

Stem cells are roughly divided into two categories: embryonic stem cells and somatic (tissue) stem cells. Among somatic stem cells, hematopoietic stem cells have attracted attention since a long time ago. The self-replication ability and pluripotency of hematopoietic stem cells are required for maintaining ma-



ture blood cells having a short life time during the life-span of a human. This has already been proposed in 1961 (Till, J.E., et al., Radiat. Res. 14: 213-222). In 1972, a bone marrow transplantation method using a mouse model was established (Micklem, H.S., et al.: J. Cell Physiol., 79: 293-298, 1972), thereby making it possible to detect hematopoietic stem cells by investigating reconstruction of the hematopoietic stem cell system. Since then, hematopoietic stem cell research has made dramatic progress. Subsequent studies revealed the presence of hematopoietic stem cells having self-replication ability and pluripotency (Dick, J.E., et al.; Cell 42: 71-79, 1985). However, hematopoietic stem cells are present at a low rate of several in about 100,000 bone marrow cells even in the case of mice. Therefore, in actual research or clinical application, hematopoietic stem cells need to be concentrated or purified.

Conventionally, hematopoietic stem cell transplantation therapies have been carried out using naturally-occurring cells, leading to various side effects. For example, a side effect (RRT) is produced by pre-treatment before transplantation using a large dose of an anticancer drug or radiation. There are also other side effects as follows: bacterial or fungal infectious diseases and hemorrhage due to suppression of bone marrow; in the case of allotransplantation, when donor's leucocytes survive and the number of the cells is increased, they recognize recipient organs as foreign matter and attack them (graft versus host diseases (GVHD)); various pulmonary complications, mainly including cytomegalovirus (CMV) pneumonia; various vis-



ceral disorders due to disorders of vascular endothelial cells (cells lining the inner wall of blood vessels); various infectious diseases during immune suppression prolonged after survival of transplanted cells  
5 (at least 1-2 years); prolonged chronic GVHD exhibiting various symptoms; late-onset disorders (e.g., secondary cancers, gonad dysfunction, infertility, etc.); and the like.

10           Due to the above-described complications, transplantation often temporarily worsens systemic conditions. The death rate of patients due to complications is about 10 to 20% in autotransplantation and about 20  
15 to 40% in allotransplantation. Even if patients overcome complications, some patients may relapse. Thus, the current transplantation therapies are inadequate.

          To prevent early death due to complications after bone marrow transplantation, a therapeutic method has  
20 been developed in which stem cells are separated and purified and precursor cells are produced in large quantities from the stem cells, and the precursor cells as well as stem cells are transplanted. The method has already entered clinical trials.

25           On the other hand, gene therapy, in which a gene is introduced into stem cells which are in turn transplanted into a patient, has been tried. For example, it has been reported that a stem cell (CD34 positive bone mar-  
30 row cell) having introduced IL-2 receptor  $\gamma$  chain was transplanted into patients with X-linked severe combined immunodeficiency, and as a result, the clinical condition of the patients was improved (Cavazzana-Calvo,



M. et al., Science, 288:669-672, 2000). When introducing a gene into a stem cell, it is necessary to culture such a stem cell for a short period of time, and it is crucial to the success of the gene therapy whether or not such a stem cell is controlled not to survive without differentiation during such a culture period.

Fluorescence activated cell sorting (FACS) was developed in the 1980's. Since then, techniques utilizing FACS have been employed for enrichment and purification of hematopoietic stem cells. It has been revealed that high-purity hematopoietic stem cells are obtained by separating CD34-KSL cells from multiply stained bone marrow cells (Osawa, M. et al., Science, 273: 242-245, 1996). As described above, pluripotency and self-replication ability are the essential features of stem cells. To exploit these abilities, it is important to enrich and purify stem cells and expand the cells by *ex vivo* culture.

Various proteins have an important role in regulating the expansion and differentiation of stem cells. For example, stem cell factor (SCF) (also called steel factor) in hematopoietic stem cells has attracted attention.

SCF is produced by bone marrow stromal cells and acts on pluripotent stem cells, bone marrow cells such as CFU-M, CFU-Meg or the like, and lymphocyte precursory cells to support their expansion and differentiation. That is, it is believed that SCF acts on cells from hematopoietic stem cells to precursory cells so as to aid other cytokines which induce differentiation to-



ward the final stage (S. Kitamura, Saitokain-no-Saizensen [Frontline of Cytokine], Yodo-sha, edited by T. Hirano, pp. 174-187, 2000).

5           However, the action of a sole SCF seems to be so  
weak that it cannot work well unless it operates in co-  
operation with other factors. For example, SCF induces  
the differentiation and expansion of hematopoietic stem  
10   cells strongly in the presence of other cytokines, such  
as interleukin IL-3, IL-6, IL-11, granulocyte colony  
stimulating factor (G-CSF), or the like. SCF also in-  
duces the differentiation and expansion of mast cells,  
erythroblast precursory cells, granulocyte macrophage  
precursory cells, megakaryocyte precursory cells, and  
15   the like.

          Therefore, it is considered that SCF does not di-  
rectly control expansion and differentiation, but en-  
hances the responsiveness of a number of kinds of hema-  
20   topoietic cells to various cytokines while supporting  
the survival of the cells.

          Thrombopoietin (TPO) has also attracted attention.  
This factor supports the differentiation of megakaryo-  
25   cytes and the production of platelets as well as acting  
on stem cells to induce their expansion and differen-  
tiation. Also, it has been found that TPO is involved  
in the self replication of stem cells.

30           Thus, conventional factors can promote the dif-  
ferentiation of stem cells in an uncontrollable manner,  
but not in a controllable manner.



Therefore, it is an object of the present invention to provide a method and substance to maintain the pluripotency of a stem cell maintaining an undifferentiated state (without differentiation).

5

#### SUMMARY OF INVENTION

Accordingly, the present invention provides a protein having a Wnt-inhibitory factor (WIF) domain.  
10 More specifically, the protein having the WIF domain is WIF-1 (for example, SEQ ID NOS: 2, 4, 6, 8, 10 or the like). A protein having a WIF domain such as WIF-1 can provide to stem cells the ability to optionally reserve pluripotency without differentiation when provided to  
15 the stem cell in combination with an agent for supporting stem cell survival such as a SCF. Previously, proteins having a WIF domain have been shown to inhibit the function of WNT protein. However, it is not known that such a protein acts on a stem cell to maintain the  
20 undifferentiated state and pluripotency and to stop differentiation. Therefore, this fact can be recognized to be a significant effect.

Therefore the present invention provides the following:  
25

1. A polypeptide having a WIF domain which maintains pluripotency without differentiating a stem cell.
2. The polypeptide according to item 1, wherein the WIF  
30 domain comprises at least five amino acids among about position 30 to about position 180 of the sequence set forth in SEQ ID NO: 4.
3. The polypeptide according to item 1, wherein the WIF



domain comprises the sequence of about position 30 to about position 180 of the sequence set forth in SEQ ID NO: 4.

4. The polypeptide according to item 1, wherein the polypeptide further includes an Epidermal Growth Factor (EGF) like repeat.
5. The polypeptide according to item 4, wherein the EGF like repeat comprises at least one repeat consisting of  $CX_3CX_3CX_3CX_3CX_4$  where C is cysteine and X is any amino acid.
6. The polypeptide according to item 1, wherein the polypeptide has the sequence set forth in SEQ ID NO: 4.
7. The polypeptide according to item 1, wherein the stem cell is a hematopoietic stem cell.
8. A composition for maintaining pluripotency without differentiating a stem cell comprising a polypeptide having a WIF domain.
9. The composition according to item 8, wherein the polypeptide further has an EGF like repeat.
10. The composition according to item 8 wherein the polypeptide has the sequence set forth in SEQ ID NO: 4.
11. The composition according to item 8 further comprising a stem cell survival agent.
12. The composition according to item 8, wherein the stem cell survival agent is stem cell factor (SCF).
13. A stem cell which does not differentiate *in vitro* and maintains pluripotency.
14. The stem cell according to item 13 which is a hematopoietic stem cell.
15. The stem cell according to item 13 wherein the period of said pluripotency maintenance is at least six days.
16. The stem cell according to item 13, wherein the



pluripotency comprises a capability of differentiating into blood cells.

17. A long period pluripotency maintaining cell composition comprising a stem cell and a polypeptide having a WIF domain.

18. The long period pluripotency maintaining cell composition according to item 17, wherein the polypeptide further comprises an EGF like repeat.

19. The long period pluripotency maintaining cell composition according to item 17, wherein the stem cell is hematopoietic cell.

20. The long period pluripotency maintaining cell composition according to item 17, wherein at least  $10^2$  cells of the stem cell exist therein.

21. The long period pluripotency maintaining cell composition according to item 17, wherein the polypeptide having the WIF domain comprises the sequence set forth in SEQ ID NO: 4.

22. The long period pluripotency maintaining cell composition according to item 17, wherein the polypeptide having the WIF domain is present at least at 0.1 ng/ml therein.

23. The long period pluripotency maintaining cell composition according to item 17 further comprising a stem cell survival agent.

24. The long period pluripotency maintaining cell composition according to item 23, wherein the stem cell survival agent is SCF.

25. The long period pluripotency maintaining cell composition according to item 23, wherein the stem cell survival agent is FLT-3 ligand.

26. The long period pluripotency maintaining cell composition according to item 23, wherein the stem cell



survival agent is present at least at 1 ng/ml therein.

27. The long period pluripotency maintaining cell composition according to item 23 for preparing differentiated cells wherein the differentiated cells are used  
5 for treating disorders of blood cells.

28. A method for maintaining pluripotency without differentiating a stem cell, comprising the step of:

1) providing the stem cell with a polypeptide having a WIF domain.

10 29. The method according to item 28 wherein the polypeptide further comprises an EGF like domain.

30. The method according to item 28 wherein the stem cell is a hematopoietic cell.

15 31. The method according to item 28 wherein the stem cell is present at least at  $10^2$  cells.

32. The method according to item 28 wherein the polypeptide having the WIF domain comprises the sequence set forth in SEQ ID NO: 4.

20 33. The method according to item 27 wherein the polypeptide having the WIF domain is present at least at 0.1 ng/ml.

34. The method according to item 27 further comprising the step of:

25 2) providing a stem cell survival agent with the stem cell.

35. The method according to item 34, wherein the stem cell survival agent is SCF.

36. The method according to item 34, wherein the stem cell survival agent is FLT-3 ligand.

30 37. The method according to item 34 wherein the stem cell survival agent is present at least at 1 ng/ml.

38. A method for producing a long period pluripotency maintaining cell composition comprising the steps of:



- 1) providing a stem cell;
  - 2) treating the stem cell with a polypeptide having a WIF domain; and
  - 3) collecting the stem cell treated.
- 5 39. The method according to item 38 wherein the polypeptide having the WIF domain further comprises an EGF like repeat.
40. The method according to item 38 wherein the stem cell is a hematopoietic stem cell.
- 10 41. The method according to item 38 wherein the stem cell is present at least at  $10^2$  cells.
42. The method according to item 38, wherein the polypeptide having the WIF domain comprises the sequence set forth in SEQ ID NO: 4.
- 15 43. The method according to item 38, wherein the polypeptide having the WIF domain is present at least at 0.1 ng/ml.
44. The method according to item 38 further comprising the step of
- 20 2) providing the stem cell with a stem cell survival agent.
45. The method according to item 44 wherein the stem cell survival agent is SCF.
46. The method according to item 44 wherein the stem cell survival agent is flt-3 ligand.
- 25 47. The method according to item 44, wherein the stem cell survival agent is present at least at 1 ng/ml.
48. A method for treating a disease or disorder originating from a disorder of a differentiated cell, comprising the steps of:
- 30 1) administering a long period pluripotency maintaining cell composition to a subject wherein the long period pluripotency maintaining cell composition com-



prises:

a stem cell; and

a polypeptide having a WIF domain.

49. The method according to item 48, wherein the polypeptide having the WIF domain further comprises an EGF-like repeat.
50. The method according to item 48 wherein the differentiated cell is a blood cell.
51. The method according to item 48 wherein the stem cell is a hematopoietic cell.
52. The method according to item 48 wherein the stem cell is present at least at  $10^2$  cells.
53. The method according to item 48 wherein the polypeptide having the WIF domain comprises the sequence set forth in SEQ ID NO: 4.
54. The method according to item 48 wherein the polypeptide having the WIF domain is present at least at 0.1 ng/ml.
55. The method according to item 48 wherein the long period pluripotency maintaining cell composition further comprises a stem cell survival agent.
56. The method according to item 55 wherein the stem cell survival agent is SCF.
57. The method according to item 55 wherein the stem cell survival agent is flt-3 ligand.
58. The method according to item 55, wherein the stem cell survival agent is present at least at 1 ng/ml.
59. The method according to item 48 further comprising the step of differentiating the stem cell.
60. The method according to item 48 wherein the subject is a human.
61. The method according to item 48 wherein the polypeptide having the WIF domain is a human recombinant



WIF-1 comprising the sequence set forth in SEQ ID NO: 4.

62. A pharmaceutical composition for treating a disease or disorder originating from a disorder of a differentiated cell comprising:

- 5           a stem cell;
- a polypeptide having a WIF domain; and
- a pharmaceutically acceptable carrier.

63. A pharmaceutical composition according to item 62 wherein the polypeptide further comprises an EGF-like  
10 repeat.

64. The pharmaceutical composition according to item 62 wherein the differentiated cell is a blood cell.

65. The pharmaceutical composition according to item 62 wherein the stem cell is a hematopoietic cell.

15 66. The pharmaceutical composition according to item 62 wherein the stem cell is present at least at  $10^2$  cells.

67. The pharmaceutical composition according to item 62 wherein the polypeptide having the WIF domain is WIF-1.

20 68. The pharmaceutical composition according to item 62 wherein the polypeptide having the WIF domain is present at least at 0.1 ng/ml.

69. The pharmaceutical composition according to item 62 further comprising a stem cell survival agent.

25 70. The pharmaceutical composition according to item 62, wherein the stem survival agent is SCF.

71. The pharmaceutical composition according to item 69, wherein the stem cell survival agent is flt-3 ligand.

72. The pharmaceutical composition according to item 69 wherein the stem cell survival agent is present at  
30 least at 1 ng/ml.

73. The pharmaceutical composition according to item 69 wherein the disease or disorder is a human disease or disorder.



74. The pharmaceutical composition according to item 74 wherein the polypeptide having the WIF domain is recombinant human WIF-1 comprising the sequence set forth in SEQ ID NO: 4.
- 5 75. Use of a polypeptide having a WIF domain for maintaining the pluripotency of a stem cell without differentiation.
76. The use according to item 75 wherein the polypeptide further comprises an EGF like repeat.
- 10 77. The use according to item 75, wherein the stem cell is a hematopoietic cell.
78. The use according to item 75, wherein the stem cell is present at least at  $10^3$  cells.
79. The use according to item 75, wherein the polypeptide having the WIF domain comprises the sequence set forth in SEQ ID NO: 4.
- 15 80. The use according to item 75, wherein the polypeptide having the WIF domain is present at least at 0.1 ng/ml.
- 20 81. The use according to item 75, combined with the use of a stem cell survival agent.
82. The use according to item 81, wherein the stem cell survival agent is SCF.
83. The use according to item 81, wherein the stem cell survival agent is flt-3 ligand.
- 25 84. The use according to item 81, wherein the stem cell survival agent is present at least at 1 ng/ml.
85. The use according to item 75 wherein the disease or disorder is a human disease or disorder.
- 30 86. The use according to item 75 wherein the polypeptide having the WIF domain is human recombinant WIF-1 comprising the sequence set forth in SEQ ID NO: 4.



## BRIEF DESCRIPTION OF DRAWINGS

Figures 1 (Figure 1A and Figure 1B) shows the WIF-1 gene in which the domains thereof are shown separately. The sequences are shown for mouse, human, rat, Xenopus, Zebrafish (corresponding to SEQ ID Nos: 2, 4, 6, 8, and 10, respectively) in that order from the top, respectively. The amino acid residues from about position 30 to about position 180 correspond to the WIF domain as defined herein. After about position 180 of the amino acid residues is located an EGF-like repeat.

Figure 2 shows a scheme showing a method for purifying CD34<sup>+</sup>KSL cells using FACS.

15

Figure 3 shows a FACS figure developed using Lin<sup>-</sup> and c-Kit<sup>+</sup>/Sca-1<sup>+</sup>.

Figure 4 shows a scheme showing a single cell culture. The cell survival rate, cell division, and colony formation of the cells prepared by the method can be analyzed using the method described herein.

20

Figure 5 shows a scheme for analyzing a stem cell using a mouse.

25

## BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the present invention will be described. It should be understood throughout the present specification that articles for a singular form (e.g., "a", "an", "the", etc. in English; "ein", "der", "das", "die", etc. and their inflections in German; "un",

30



"une", "le", "la", etc. in French; "un", "una", "el", "la", etc. in Spanish, and articles, adjectives, etc. in other languages) include the concept of their plurality unless otherwise mentioned. It should be also understood that the terms as used herein have definitions typically used in the art unless otherwise mentioned.

(Description of the sequences)

10 SEQ ID NO: 1 shows the full-length nucleotide sequence of murine WIF-1 of the present invention.

SEQ ID NO: 2 shows the full-length amino acid sequence of murine WIF-1 of the present invention.

15 SEQ ID NO: 3 shows the full-length nucleotide sequence of human WIF-1 of the present invention.

SEQ ID NO: 4 shows the full-length amino acid sequence of human WIF-1 of the present invention.

SEQ ID NO: 5 shows the full-length nucleotide sequence of rat WIF-1 of the present invention.

20 SEQ ID NO: 6 shows the full-length amino acid sequence of rat WIF-1 of the present invention.

SEQ ID NO: 7 shows the full-length nucleotide sequence of Xenopus WIF-1 of the present invention.

25 SEQ ID NO: 8 shows the full-length amino acid sequence of Xenopus WIF-1 of the present invention.

SEQ ID NO: 9 shows the full-length nucleotide sequence of Zebrafish WIF-1 of the present invention.

SEQ ID NO: 10 shows the full-length amino acid sequence of Zebrafish WIF-1 of the present invention.

30 SEQ ID NO: 11 shows a sequence of a degenerate primer (forward direction) used in Example 1.

SEQ ID NO: 12 shows a sequence of a degenerate primer (backward direction) used in Example 1.



As used herein, including SEQ ID NOS: 11 and 12, the nucleic acid references used are as follows: a: adenine; c: cytosine; g: guanine; t: thymine; u: uracil; m: a or c; r: g or a; w: a or t or u; s: g or c; y: t or u or c; k: g or t or u; v: a or g or c; h: a or c or t or u; d: a or g or t or u; b: g or c or t or u; n: (a or c or g or t or u) or (unknown or other base).

SEQ ID NO: 13 shows the sequence of pCAGGS-6His vector.

SEQ ID NOS: 14, 16, 18, and 20 show nucleotide sequences of conservatively substituted variants of the polypeptide containing the WIF domain of the present invention, and SEQ ID NOS: 15, 17, 19 and 21 show the amino acid sequence of the conservatively substituted variants of the polypeptide having the WIF domain of the present invention.

SEQ ID NO: 22 shows the nucleotide sequence of a variant comprising only the WIF domain.

SEQ ID NO: 23 shows the amino acid sequence of a variant comprising only the WIF domain.

SEQ ID NO: 24 shows the nucleotide sequence of a variant comprising only the EGF-like repeat.

SEQ ID NO: 25 shows the amino acid sequence of a variant comprising only the EGF-like repeat.

#### (Definition of the terms)

The term "cell" is herein used in its broadest sense in the art, referring to a structural unit of tissue of a multicellular organism, which is capable of self replicating, has genetic information and a mechanism for expressing it, and is surrounded by a membrane structure which isolates the cell from the outside.



As used herein, any cell may be used so long as the cell can obtain the capability of obtaining pluripotency and becoming undifferentiated cell by treating the cell with an agent of the present invention, although stem cells may usually be used. As used herein, the term "stem cell" refers to a cell capable of self replication and pluripotency. Typically, stem cells can regenerate an injured tissue. As used herein "life" of a stem cell refers to a phenomenon wherein survival or growth in an undifferentiated state without loss of pluripotency occurs. The "death" of a stem cell refers to a phenomenon leading to differentiation or apoptosis. Stem cells used herein may be, but are not limited to, embryonic stem (ES) cells or tissue stem cells (also called tissular stem cells, tissue-specific stem cells, or somatic stem cells). Embryonic stem cells are pluripotent stem cells derived from early embryos. An embryonic stem cell was first established in 1981, and has been applied to the production of knockout mice since 1989. In 1998, a human embryonic stem cell line was established, which is currently becoming available for regenerative medicine. Therefore in a preferable embodiment of the present invention, embryonic stem cells or embryonic germ cells may be used as the cell. In another preferable embodiment, tissue stem cells such as hematopoietic stem cells are used.

Tissue stem cells have a relatively limited level of differentiation unlike embryonic stem cells. Tissue stem cells are present in tissues and have an undifferentiated intracellular structure. Tissue stem cells have a higher nucleus/cytoplasm ratio and have few in-



tracellular organelles. Most tissue stem cells have pluripotency, a long cell cycle, and proliferative ability beyond the life of the individual. Accordingly, in a preferable embodiment of the present invention, tissue stem cells which are directed to blood cells are used as the cell.

Tissue stem cells are separated into categories of sites from which the cells are derived, such as ectodermic, mesodermic and endodermic. Tissue stem cells in the dermal system include nervous stem cells present in the brain and epidermal stem cells, hair follicle stem cells and pigment stem cells found in the skin, and the like. Tissue stem cells in the mesoderm system include blood vessel stem cells, hematopoietic stem cells, and mesenchymal stem cells found in the bone marrow and blood. Tissue stem cells in the endoderm are mainly present in the organs and include hepatic stem cells, pancreatic stem cells, bowel and epidermal stem cells. In addition, germ line stem cells are present in the testis and ovary. In a preferable embodiment of the present invention, stem cells in the mesoderm system may be used. In a more preferable embodiment of the present invention, hematopoietic stem cells may be used.

Tissue stem cells are separated into categories of sites from which the cells are derived, such as the dermal system, the digestive system, the bone marrow system, the nervous system, and the like. Tissue stem cells in the dermal system include epidermal stem cells, hair follicle stem cells, and the like. Tissue stem cells in the digestive system include pancreatic (com-



mon) stem cells, hepatic stem cells, and the like. Tissue stem cells in the bone marrow system include hematopoietic stem cells, mesenchymal stem cells, and the like. Tissue stem cells in the nervous system include  
5 neural stem cells, retinal stem cells, and the like. In an embodiment of the present invention, hematopoietic stem cells may be used as the blood cells are derived from the hematopoietic stem cells.

10 Hematopoietic stem cells are one of the most studied stem cells up to date. However, hematopoietic stem cells are not completely understood on a number of points such as the plasticity thereof. Mouse models are mostly used for studying hematopoietic stem cells. He-  
15 matopoietic stem cells are present at about 3 to 4 cells per 100,000 bone marrow cells (in the case of the B6 mouse). When hematopoietic stem cells are applied to experiments or therapy, it is necessary to separate them from the other bone marrow cells. The most effi-  
20 cient way at present for purifying such hematopoietic stem cells is a method for enriching hematopoietic stem cells comprising staining bone marrow cells using an antibodies labeled with a fluorescence labeled against  
25 a number of cell surface antigen, separating them into positive and negative cell fractions using FACS, and selecting the fractions containing hematopoietic stem cells.

Hematopoietic stem cells in the bone marrow are  
30 frequently present in CD34 negative or weakly positive, c-Kit positive, Sca-1 positive, lineage marker negative (CD34<sup>+</sup>KSL) cell fractions. It is known that a competitive repopulation assay can be used to stimulate hema-



topoietic repopulation for a longer period of time at a ratio of about one per three recipient mice when a CD34<sup>+</sup>KSL cell is transplanted into a mouse. Therefore, one in three CD34<sup>+</sup>KSL cells can be recognized to be a hematopoietic stem cell (Jikken Igaku = Experimental Medicine, Vol. 19, No. 15 (Suppl.) 55-59, 2001). As the level of repopulation is heterogeneous, hematopoietic stem cell population is not homogeneous. Such hematopoietic stem cell enriched populations can be well used in experimental and clinical applications.

In the present invention, such enriched or purified hematopoietic stem cells populations may be used as a cell source.

15

As used herein, the term "differentiated cell" refers to a cell having a specialized function and form (e.g., muscle cells, neurons, blood cells, etc.). Unlike stem cells, differentiated cells have no or little pluripotency. Examples of differentiated cells include epidermic cells, pancreatic parenchymal cells, pancreatic duct cells, hepatic cells, bile duct cells, blood cells (such as red blood cells, platelets, T cells, B cells or the like), cardiac muscle cells, skeletal muscle cells, osteoblasts, skeletal myoblasts, neurons, vascular endothelial cells, pigment cells, smooth muscle cells, adipocytes, bone cells, cartilage cells, and the like. Therefore, in an embodiment of the present invention, when a differentiated cell can be treated by an agent of the present invention to maintain an undifferentiated state and to obtain pluripotency, such a differentiated cell falls within the scope of the present invention. A differentiated cell

30



prepared from the stem cell of the present invention can be used for the treatment and/or the prevention of a variety of diseases and disorders. Accordingly, such a differentiated cell and a composition comprising such a differentiated cell will also fall within the scope of the present invention. Such a differentiated cell can be prepared by the application of differentiation factors (for example, hematopoietic factors such as erythropoietin (EPO), a variety of interleukins (such as IL-3) or the like). As used herein the term "differentiation factor" is an agent (such as a polypeptide) for promoting differentiation by acting on a stem cell. Examples of such differentiation factors include cytokines including a variety of interleukins (such as IL-3, IL-6, IL-11 or the like), colony stimulating factor (such as EPO, thrombopoietin (TPO), granulocyte-colony stimulating factor (G-CSF), granulocyte-macrophage-colony stimulating factor (GM-CSF), macrophage-colony stimulating factor (M-CSF) or the like); a variety of growth factors including Hepatic growth factor (HGF), Epidermal Growth Factor (EGF), Vascular Endothelial growth factor (VEGF), Platelet-Derived Growth factor (PDGF), and Fibroblast Growth Factor (FGF).

As used herein, the term "isolated" refers to a status of a substance or a cell, and that the substance or cell is in a different status than that of the natural state, and means that at least one substance or cell, which naturally associates therewith, does not associate. As used herein, the term "concentration" or "enrichment" of a cell refers to elevating the occurrence of a specific cell present from that of the naturally occurring state. As used herein, the term "puri-



fication" of a cell refers to bringing the frequency of the cell to a higher level, and cells other than the cells of interest will be present in a manner such that the function of the cells of interest will be substantially unaffected. Accordingly, in a preferable state, purified cells or cell compositions comprise particular cells only. As used herein "purifying" a substance refers to bringing the frequency of the substance to a higher level, and substances other than the substance of interest will be present in a manner such that the function of the substances of interest will be substantially unaffected. Accordingly, in a preferable state, purified substance or compositions comprising the same will comprise a particular substance only.

15

Further, cells having pluripotency of the present invention can differentiate into at least a blood-lymphoid system cell (T cell, B cell, plasma cell, basophil, eosinophil, monocyte, macrophage, neutrophil, megakaryocyte, platelet, erythroblast, erythrocyte or the like), and preferably the cells having pluripotency of the present invention can differentiate into all the blood-lymphoid system cells. Accordingly, the preferable differentiated cells of the present invention may be a blood-lymphoid system cells such as T cells, B cells, plasma cells, megakaryocytes, platelets, erythroblasts, erythrocytes and the like.

As used herein, the terms "differentiation" or "cell differentiation" refers to a phenomenon that two or more types of cells having qualitative differences in form and/or function occur in a daughter cell population derived from the division of a single cell.



Therefore, "differentiation" includes a process during which a population (family tree) of cells, which do not originally have a specific detectable feature, acquires a feature, such as the production of a specific protein, or the like. At present, cell differentiation is generally considered to be a state of a cell in which a specific group of genes in the genome are expressed. Cell differentiation can be identified by searching for intracellular or extracellular agents or conditions which elicit the above-described state of gene expression. Differentiated cells are stable in principle. Particularly, animal cells which have been once differentiated are rarely differentiated into other types of cells. Therefore, the acquired pluripotent cells of the present invention are considerably useful. "Undifferentiated (state)" refers to a state of a cell in which the cell has no qualitative difference in forms or functions.

As used herein, the term "pluripotency" refers to a nature of a cell, i.e., an ability to differentiate into a variety of tissues or organs. Typically, the pluripotency of a cell is limited as the cell is developed, and in an adult, where the pluripotency is usually lost, cells constituting a tissue or organ rarely alter to different cells. Particularly, epithelial cells resist altering to other types of epithelial cells. Such alteration typically occurs in pathological conditions, and is called metaplasia. However, mesenchymal cells tend to easily undergo metaplasia, i.e., alter to other mesenchymal cells, with relatively simple stimuli. Therefore, mesenchymal cells have a high level of pluripotency. Therefore, the term "maintaining



pluripotency" refers to maintenance of a pluripotency of cells such as stem cells. The present invention is a breakthrough invention which has attained the production of a stem cell which can maintain pluripotency for a longer period of time than a normal stem cell.

Cells used herein may be derived from any organism (e.g., vertebrates and invertebrates). Preferably, cells from a vertebrate are used and more preferably, cells from a mammal such as primates, rodentia etc. are used. Still more preferably, cells from primates are used. Most preferably, cells from humans are used.

As used herein the term "WIF domain" refers to a N-terminal region of the WIF-1 protein without the signal peptide thereof and extending until the EGF-like repeat starts. Therefore, in the case of the murine WIF domain, such a domain corresponds to the amino acid number about position 30 to about position 180 in the sequence of SEQ ID NO: 2. As used herein, the "WIF domain" will include, in addition to the identical sequence of the amino acid number about position 30 to at about position 180 of SEQ ID NO: 2, the identical sequence of the amino acid number at about position 30 to at about position 180 of human WIF domain as set forth in SEQ ID NO: 4, the identical sequence of the amino acid number at about position 30 to at about position 180 of the Xenopus WIF domain as set forth in SEQ ID NO: 8, the identical sequence of the amino acid number at about position 30 to at about position 180 of the Zebrafish WIF domain as set forth in SEQ ID NO: 10, as well as similar sequences thereof. As used herein, such similar sequences are preferably conservatively substituted



variants of a sequence selected from the group consisting of the WIF domains of the mouse, human, Xenopus and Zebrafish sequences as described above. Conservative substitution is defined hereinbelow. In the present invention, a polypeptide having a WIF domain of the above-mentioned length is usually used, however, a polypeptide having a WIF domain having a shorter length than the WIF domain may be used. Such a polypeptide having a WIF domain having a shorter length than the WIF domain can be readily determined to have a function of the WIF domain by the use of an *in vitro* inhibition activity assay for the Wnt protein as set forth in Hsieh J.H., et al., Nature 398,431-436, 1999. Accordingly, such a shorter WIF domain will include, among the group of the identical sequence of the amino acid number at about position 30 to at about position 180 of SEQ ID NO: 2, the identical sequence of the amino acid number at about position 30 to at about position 180 of human WIF domain as set forth in SEQ ID NO: 4, the identical sequence of the amino acid number at about position 30 to at about position 180 of the Xenopus WIF domain as set forth in SEQ ID NO: 8, and the identical sequence of the amino acid number at about position 30 to at about position 180 of the Zebrafish WIF domain as set forth in SEQ ID NO: 10, at least 5 amino acids, at least 6 amino acids, at least 7 amino acids, at least 8 amino acids, at least 9 amino acids, at least 10 amino acids, at least 11 amino acids, at least 12 amino acids, at least 13 amino acids, at least 14 amino acids, at least 15 amino acids, at least 20 amino acids, at least 25 amino acids, at least 30 amino acids, at least 40 amino acids, at least 50 amino acids, at least 60 amino acids, at least 70 amino acids, at least 80 amino acids,



at least 90 amino acids, at least 100 amino acids, at least 110 amino acids, at least 120 amino acids, at least 130 amino acids, at least 140 amino acids, or at least 150 amino acids of this group. As used herein, a preferable polypeptide having a WIF domain is WIF-1. The amino acid sequences of the WIF-1 are, as used herein, SEQ ID NOs: 2, 4, 6, 8 and 10 (murine, human, rat, *Xenopus*, and Zebrafish, respectively), and these are well conserved among the species (see Figure 1).

10

As used herein, the term "EGF like repeat" refers to a specific domain in Epidermal Growth Factor. It is a repeated sequence having six cysteines in the repeat unit, and in the EGF, it has nine repeats consisting of the repeated unit "CX<sub>7</sub>CX<sub>4-5</sub>CX<sub>10-13</sub>CXCX<sub>8</sub>C" wherein X refers to any amino acid. A useful polypeptide for the present invention preferably comprises at least one EGF-like repeat, and more preferably, may have two, three, four or five EGF-like repeats. WIF-1 has five repeats consisting of the repeating unit "CX<sub>3</sub>CX<sub>5</sub>CX<sub>5</sub>CXCX<sub>8</sub>X<sub>4</sub>" wherein X refers to any amino acid. WIF-1 of the present invention has five EGF-like repeats, and the location thereof is as follows: in the case of murine WIF-1 polypeptide (SEQ ID NO: 2), amino acid numbers 182-213, 213-245, 245-277, 278-309 and 310-341. Polypeptides having an EGF-like repeat include notch-1, notch-2, jagged-1, D11-1, DLK and the like. A polypeptide having an EGF-like repeat has been shown to be involved in controlling differentiation of a stem cell in a general sense (WO 97/31467A1), however, no activity has been shown for maintaining pluripotency with blocking or delaying differentiation (i.e. maintaining the undifferentiated state) until the present invention discloses

30



such an activity in WIF-1, and therefore, the significance of the present invention should be acknowledged.

5 The cysteine residues included in the WIF-1 polypeptide are located at amino acid positions: 140, 177, 182, 186, 192, 198, 200, 209, 214, 218, 224, 230, 232, 241, 246, 250, 256, 262, 264, 273, 278, 282, 288, 294, 296, 305, 310, 314, 320, 326, 328 and 337 of SEQ ID NO: 2. These residues are conserved among species.

10

Portions to which carbohydrate chains can be added may be a portion to which an N-acetyl-D-glucosamine can be bound by N-glucoside binding, and include positions 120, 158, 170, 193, 220, 240, 245, 15 252, 284, 324 and 338. These positions are also conserved among many species. Further, a portion to which an N-acetyl-D-galactosamine can be bound by O-glucoside binding, include a portion in which serine or threonine residues are often present. These proteins with carbohydrates added are usually stable against degradation 20 *in vivo* and may have more potent physiological activity. Accordingly, these polypeptide with carbohydrate added are also within the scope of the present invention.

25 The polypeptides of the present invention may be from any organism. Preferably, the organism is a vertebrate (such as mammals, reptiles, amphibians, fish, avifauna etc.), more preferably, mammals (for example, rodentia (mouse, rat, etc.), primates (such as humans) 30 etc.). In another embodiment, the polypeptide of the present invention may be synthesized. Methods for synthesizing amino acids are well known in the art. Such a synthesizing method includes methods utilizing peptide



synthesizers (such as those available from Applied Biosystems and the like).

The polypeptide of the present invention may use  
5 polymeric (such as dimeric or higher) type polypeptides  
having more potent specific activity comprising a fusion protein produced by a method for forming dimers using disulfide bonds by expressing a fusion protein with a single hinge region portion of an antibody, or a  
10 fusion protein produced to be expressed at the C-terminus, N-terminus, or other site in a form such that a disulfide bond is formed by any different method not affecting the activity of the polypeptide. Further, a method for producing a polymeric structure by aligning  
15 a sequence of the present invention such as SEQ ID NO: 2 in tandem, may be used. Accordingly, any dimers or polymers higher order oligomer produced by genetic engineering technology is also within the scope of the present invention.

20

As used herein, the term "stem cell survival agent" is an agent considered to be essential for survival of a stem cell. Conventionally, the survival (and differentiation) of stem cells has been thought to require SCF. However, Ornitz M., et  
25 al. (Immunity, Vol. 10, 173-182, 1999) discovered a pluripotent hematopoietic stem cell which does not express c-Kit which is a receptor for SCF. Therefore, SCF *per se* is not required for survival of all stem cells. Thus,  
30 those skilled in the art understand that a stem cell survival agent may vary depending on the stem cell of interest.



Accordingly, those skilled in the art will recognize that stem cell survival agents will vary depending on the stem cell used. Stem cell survival agents include SCF, TPO, flt-3 ligand and the like. In one embodiment, a stem cell survival agent may be SCF (also known as steel factor). SCF was identified as an agent for controlling stem cell function. However, as described herein, SCF per se has no activity relating to self-replication of stem cells, and rather it became apparent that SCF supports the survival of cells having the c-Kit receptor, and directs cells to differentiation as a result. Accordingly, SCF is considered to serve as a species of stem cell survival agent and is a preferred example of stem cell survival agent herein.

15

Further, conventionally, a positive CD34 indication is considered to be an important marker for pluripotency, and the expression thereof has been considered to be indicative of having pluripotency. However, it has herein become apparent that such a positive indication is not always correlated with pluripotency. Thus, in the present invention, the surprising finding that a protein having WIF domain has a function of maintaining pluripotency without inducing differentiation of stem cells has been made.

25

As a ligand of Notch, Jagged-1 is known (J.Exp.Med. 192,1365-1372,2000). Jagged-1 has been shown to have relation with hematopoietic cells, however, it has not been shown that Jagged-1 alone or in combination with SCF has a function of maintaining pluripotency with an undifferentiated state.

30



Hematopoietic factors such as TPO have been shown to be related to differentiation control in hematopoietic stem cells. Blood, 1 October 2001, Vol. 98, No. 7, pp. 2091-2100 showed the roles of survivin, which is a member of the family of apoptosis suppression factors, in normal umbilical cord blood and bone marrow CD34 positive cells in relation to hematopoietic factors. The combination of TPO, Flt3 ligand (FL) and SCF was shown to upregulate the expression of survivin in CD34+ cells within 24 hours. Further, it was shown that the expression of survivin and the entry into the cell cycle coincide with each other. However, no relationship has been studied with cell differentiation.

As used herein, the terms "protein", "polypeptide" and "peptide" are interchangeably used to refer to a macromolecule (polymer) consisting of a series of amino acids. Amino acid refers to an organic molecule having carboxyl and amino groups on a carbon atom. As used herein, preferably, such an amino acid may be, but is not limited to, one of the twenty naturally-occurring amino acids.

The terms "polynucleotide", "oligonucleotide", and "nucleic acid" as used herein have the same meaning and refer to a nucleotide polymer having any length. Nucleotide refers to a nucleoside in which a portion is replaced with phosphate ester. The base portion thereof includes pyrimidine bases or purine bases (such as pyrimidine nucleotides and purine nucleotides). Polynucleotides include DNA and RNA.

A method for producing the polypeptide of the



present invention includes, for example, a method for culturing primary cells or cell lines producing the polypeptide and isolating or purifying the protein from the culture supernatant thereof. Alternatively, it is possible to use genetic engineering methods, to incorporate a gene encoding the polypeptide into an appropriate expression vector, to transform an expression host with the vector and to obtain a recombinant physiologically active substance (for example, cell growth factor) from the culture supernatant of the transformed cells. The host cell includes but is not limited to any cell so long as the cell expresses the polypeptide, and those skilled in the art can use a variety of host cells that can be used in the art for genetic engineering, such as *E. coli*, yeast, plant cells, insect cells, animal cells, and the like. The polypeptide thus obtained can be used so long as the polypeptide has the substantially similar activity and can include one or more amino acid substitutions, additions and/or deletions in an amino acid sequence, and one or more carbohydrate chain can be substituted, added and/or deleted.

A given amino acid may be substituted with another amino acid in a protein structure, such as a cationic region or a substrate molecule binding site, without a clear reduction or loss of interactive binding ability. A given biological function of a protein is defined by the interactive ability or other property of the protein. Therefore, a particular amino acid substitution may be performed in an amino acid sequence, or at the DNA code sequence level, to produce a protein which maintains the original property after the substi-



tution. Therefore, various modifications of peptides as disclosed herein and DNA encoding such peptides may be performed without clear losses of biological usefulness.

5           When the above-described modifications are designed, the hydrophobicity indices of amino acids may be taken into consideration. The hydrophobic amino acid indices play an important role in providing a protein with an interactive biological function, which is generally recognized in the art (Kyte, J. and Doolittle, R.F., J. Mol. Biol. 157(1): 105-132, 1982). The hydrophobic property of an amino acid contributes to the secondary structure of a protein and then regulates interactions between the protein and other molecules  
10 (e.g., enzymes, substrates, receptors, DNA, antibodies, antigens, etc.). Each amino acid is given a hydrophobicity index based on the hydrophobicity and charge properties thereof as follows: isoleucine (+4.5); valine (+4.2); leucine (+3.8); phenylalanine (+2.8);  
15 cysteine/cystine (+2.5); methionine (+1.9); alanine (+1.8); glycine (-0.4); threonine (-0.7); serine (-0.8); tryptophan (-0.9); tyrosine (-1.3); proline (-1.6); histidine (-3.2); glutamic acid (-3.5); glutamine (-3.5); aspartic acid (-3.5); asparagine (-3.5); lysine  
20 (-3.9); and arginine (-4.5).  
25

          It is well known that if a given amino acid is substituted with another amino acid having a similar hydrophobicity index, the resultant protein may still  
30 have a biological function similar to that of the original protein (e.g., a protein having an equivalent enzymatic activity). For such an amino acid substitution, the hydrophobicity index is preferably within  $\pm 2$ .



more preferably within  $\pm 1$ , and even more preferably within  $\pm 0.5$ . It is understood in the art that such an amino acid substitution based on hydrophobicity is efficient. As described in US Patent No. 4,554,101, amino acid residues are given the following hydrophilicity indices: arginine (+3.0); lysine (+3.0); aspartic acid (+3.0  $\pm$  1); glutamic acid (+3.0  $\pm$  1); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); threonine (-0.4); proline (-0.5  $\pm$  1); alanine (-0.5); histidine (-0.5); cysteine (-1.0); methionine (-1.3); valine (-1.5); leucine (-1.8); isoleucine (-1.8); tyrosine (-2.3); phenylalanine (-2.5); and tryptophan (-3.4). It is understood that an amino acid may be substituted with another amino acid which has a similar hydrophilicity index and can still provide a biological equivalent. For such an amino acid substitution, the hydrophilicity index is preferably within  $\pm 2$ , more preferably  $\pm 1$ , and even more preferably  $\pm 0.5$ .

The term "conservative substitution" as used herein refers to amino acid substitution in which a substituted amino acid and a substituting amino acid have similar hydrophilicity indices or/and hydrophobicity indices as described above. Examples of conservative substitution include, but are not limited to, substitutions within each of the following residue pairs: arginine and lysine; glutamic acid and aspartic acid; serine and threonine; glutamine and asparagine; and valine, leucine, and isoleucine, and the like, which are well known to those skilled in the art.

In order to prepare functionally equivalent polypeptides, amino acid additions, deletions, or modifica-



tions can be performed in addition to amino acid substitutions. Amino acid substitution(s) refers to the replacement of at least one amino acid of an original peptide chain with different amino acids, such as the replacement of 1 to 10 amino acids, preferably 1 to 5 amino acids, and more preferably 1 to 3 amino acids with different amino acids. Amino acid addition(s) refers to the addition of at least one amino acid to an original peptide chain, such as the addition of 1 to 10 amino acids, preferably 1 to 5 amino acids, and more preferably 1 to 3 amino acids to an original peptide chain. Amino acid deletion(s) refers to the deletion of at least one amino acid, such as the deletion of 1 to 10 amino acids, preferably 1 to 5 amino acids, and more preferably 1 to 3 amino acids. Amino acid modification includes, but is not limited to, amidation, carboxylation, sulfation, halogenation, truncation, lipidation, alkylation, glycosylation, phosphorylation, hydroxylation, acylation (e.g., acetylation), and the like. Amino acids to be substituted or added may be naturally-occurring or nonnaturally-occurring amino acids, or amino acid analogs. Naturally-occurring amino acids are preferable. Those skilled in the art can determine whether or not such a variant is functionally equivalent by evaluating whether or not the variant has a similar function to the indicator polypeptide using any assay described herein.

As used herein, the term "peptide analog" refers to a compound which is different from a peptide but has at least one chemical or biological function equivalent to the peptide. Therefore, a peptide analog includes one that has at least one amino acid analog or amino



acid derivative addition or substitution with respect to the original peptide. A peptide analog has the above-described addition or substitution so that the function thereof is substantially the same as the function of the original peptide (e.g., a similar pKa value, a similar functional group, a similar binding manner to ligands, a similar water-solubility, and the like). Such a peptide analog can be prepared using a technique well known in the art.

10

Such a nucleic acid molecule encoding a polypeptide used in the present invention includes one in which a part of the sequence of the nucleic acid is deleted or is substituted with other base(s), or an additional nucleic acid sequence is inserted, as long as a polypeptide expressed by the nucleic acid has substantially the same activity as that of the polypeptide of the present invention, as described above. Alternatively, an additional nucleic acid may be linked to the 5' terminus and/or 3' terminus of the nucleic acid. The nucleic acid molecule may include one that is hybridizable to a gene encoding a polypeptide under stringent conditions and encodes a polypeptide having substantially the same function. Such a method for producing such a nucleic acid is known in the art and can be used in the present invention.

The above-described nucleic acid can be obtained by a well-known PCR method, i.e., chemical synthesis. This method may be combined with, for example, site-specific mutagenesis, hybridization, or the like.

30

Molecular biological techniques, biochemical



techniques, and microorganism techniques as used herein are well known in the art and commonly used, and are described in, for example, Ausubel F.A. et al., ed., (1988), Current Protocols in Molecular Biology, Wiley, New York, NY; Sambrook J. et al., (1987) Molecular Cloning: A Laboratory Manual, 2nd Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY; Special issue, Jikken Igaku [Experimental Medicine] "Idenshi Donyu & Hatusugenkaiseki Jikkenho [Experimental Methods for Gene Introduction & Expression Analysis]", Yodo-sha, 1997, and the like.

As used herein, the term "fragment" refers to a polynucleotide having a sequence length ranging from 1 to n-1 with respect to the full length of the reference polynucleotide (of length n). The length of the fragment can be appropriately changed depending on the purpose. For example, in the case of polypeptides, the lower limit of the length of the fragment includes 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50 or more amino acids. Lengths represented by integers which are not herein specified (e.g., 11 and the like) may be appropriate as a lower limit. For example, in the case of polynucleotides, the lower limit of the length of the fragment includes 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 75, 100 or more nucleotides. Lengths represented by integers which are not herein specified (e.g., 11 and the like) may be appropriate as a lower limit.

In order to use a fragment of a nucleic acid molecule as a selective promoter or selective primer against the original nucleic acid from which it is derived, it is required to be a fragment which specifi-



cally hybridizes thereto. As used herein, DNAs which "specifically hybridize" refers to the capability of distinguishably detecting or amplifying a second nucleic acid molecule. A selective probe may be typically  
5 at least 10 nucleotides in length, preferably at least 15 nucleotides in length, more preferably at least 20 nucleotides in length, still more preferably at least 30, 40 or 50 nucleotides in length, and a length of more than 50 nucleotides can also be used. A selective  
10 probe is available as a PCR amplified product using such selective primers. When using a selective primer as at least one of a pair of primers for PCR, such a selective primer may be at least 9 nucleotides in length, preferably at least 10 nucleotides in length,  
15 more preferably at least 15 nucleotides in length, still more preferably at least 17, 18, 19, 20, 21, 22, 23, 24, 25, 30 or 50 nucleotides in length.

As used herein, "homology" of a gene refers to  
20 the proportion of identity between two or more gene sequences. Therefore, the greater the homology between two given genes, the greater the identity or similarity between their sequences. Whether or not two genes have homology is determined by comparing their sequences di-  
25 rectly or by a hybridization method under stringent conditions. When two gene sequences are directly compared with each other, these genes have homology if the DNA sequences of the genes have representatively at least 50% identity, preferably at least 70% identity,  
30 more preferably at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identity with each other.

The similarity, identity and homology of amino



acid sequences and base sequences are herein compared using BLAST (sequence analyzing tool) with the default parameters.

5           As used herein, "polynucleotides hybridizing under stringent conditions" refers to conditions commonly used and well known in the art. Such a polynucleotide can be obtained by conducting colony hybridization, plaque hybridization, southern blot hybridization, or  
10   the like using a polynucleotide selected from the polynucleotides of the present invention. Specifically, a filter on which DNA derived from a colony or plaque is immobilized is used to conduct hybridization at 65°C in the presence of 0.7 to 1.0 M NaCl. Thereafter, a  
15   0.1 to 2-fold concentration SSC (saline-sodium citrate) solution (1-fold concentration SSC solution is composed of 150 mM sodium chloride and 15 mM sodium citrate) is used to wash the filter at 65°C. Polynucleotides identified by this method are referred to as "polynucleo-  
20   tides hybridizing under stringent conditions". Hybridization can be conducted in accordance with a method described in, for example, Molecular Cloning 2nd ed., Current Protocols in Molecular Biology, Supplement 1-38, DNA Cloning 1: Core Techniques, A Practical Approach, Second Edition, Oxford University Press (1995),  
25   and the like. Here, sequences hybridizing under stringent conditions exclude, preferably, sequences containing only A (adenine) or T (thymine).

30           As used herein, "hybridizable polynucleotide" refers to a polynucleotide which can hybridize to other polynucleotides under the above-described hybridization conditions. Specifically, the hybridizable polynucleo-



tide includes at least a polynucleotide having a homology of at least 60% to the base sequence of DNA encoding a polypeptide having an amino acid sequence as set forth in SEQ ID NO:2, 4, 6 or 8, preferably a polynucleotide having a homology of at least 80%, and more preferably a polynucleotide having a homology of at least 95%. The homology of a nucleic acid sequence may be represented by similarity evaluated with a score using, for example, the search program BLAST which uses an algorithm developed by Altschul et al., J. Mol. Biol., 215, 403-410(1990)).

An "oligonucleotide derivative" includes a nucleotide derivative, or refers to an oligonucleotide having different linkages between nucleotides from typical linkages. Examples of such an oligonucleotide specifically include 2'-O-methyl-ribonucleotide, an oligonucleotide derivative in which a phosphodiester bond in an oligonucleotide is converted to a phosphorothioate bond, an oligonucleotide derivative in which a phosphodiester bond in an oligonucleotide is converted to a N3'-P5' phosphoroamidate bond, an oligonucleotide derivative in which a ribose and a phosphodiester bond in an oligonucleotide are converted to a peptide-nucleic acid bond, an oligonucleotide derivative in which uracil in an oligonucleotide is substituted with C-5 propynyl uracil, an oligonucleotide derivative in which uracil in an oligonucleotide is substituted with C-5 thiazole uracil, an oligonucleotide derivative in which cytosine in an oligonucleotide is substituted with C-5 propynyl cytosine, an oligonucleotide derivative in which cytosine in an oligonucleotide is substituted with phenoxazine-modified cytosine, an



oligonucleotide derivative in which ribose in DNA is substituted with 2'-O-propyl ribose, and an oligonucleotide derivative in which ribose in an oligonucleotide is substituted with 2'-methoxyethoxy ribose.

5

As used herein, "amino acid" may be natural or unnatural as described above. "Amino acid derivative" refers to a substance which is different from a natural amino acid but has similar function to the original amino acid. Such an amino acid derivative is well known in the art.

As used herein, "nucleotide" may be natural or unnatural as described above. "Nucleotide derivative" refers to a substance which is different from a natural nucleotide but has similar function to the original nucleotide. Such a nucleotide derivative is well known in the art.

As used herein, the term "epitope" refers to an antigenic determinant whose structure is clear. Methods for determining epitopes are well known in the art, and those skilled in the art can determine such well known and commonly used technology to produce the same once the nucleic acid or amino acid primary sequence information is available. Generally, in order to use as an epitope such a sequence requires a length of at least 3 such amino acids, and preferably, at least a length of 4, 5, 6, 7, 8, 9, 10, 15, 20 or 25 such amino acids.

30

As used herein, the term "biological activity" refers to activity possessed by an agent (e.g., a polypeptide or protein etc.) within an organism, including



activities exhibiting various functions. For example, when a given agent is an enzyme, the biological activity thereof includes the enzymatic activity thereof. In another example, when a given agent is a ligand, the biological activity thereof includes binding of the agent to a receptor for the ligand. In a protein having a WIF domain which is an embodiment of the present invention, such a biological activity includes at least one binding activity to a receptor of the Wnt family.

10

As used herein, the term "variant" refers to a substance, such as a polypeptide, polynucleotide, or the like, which differs partially from the original substance. Examples of such a variant include a substitution variant, an addition variant, a deletion variant, a truncated variant, an allelic variant, and the like. The term "allele" as used herein refers to a genetic variant located at a locus identical to a corresponding gene, where the two genes are distinguished from each other. Therefore, the term "allelic variant" as used herein refers to a variant which has an allelic relationship with a given gene. The term "species homolog" or "homolog" as used herein refers to one that has a nucleotide homology with the nucleotide sequence of a given reference nucleic acid. Homologs are typically polynucleotides which hybridize to the reference nucleic acid molecule under stringent conditions. In reference to a nucleic acid molecule of the present invention, "homolog" refers to a nucleic acid molecule having a nucleic acid sequence having homology with the nucleic acid sequence encoding the amino acid sequence of the protein, and has the same or similar biological function with that of the present invention. Accord-

30



ingly, the "homolog" and "variant" is a concept which partially overlaps to each other. The term "homolog" as used herein refers to one that has an amino acid or nucleotide homology with a given gene in a given species (preferably at least 60% homology, more preferably at least 80%, at least 85%, at least 90%, and at least 95% homology). A method for obtaining such a homolog is understood from the description of the present specification. For example, a homolog of WIF-1 of the present invention can be a homologous gene of the same species or a gene corresponding to that of the other species. Thus, the protein having a WIF domain of the present invention includes all the homologs of WIF-1.

As used herein, when it is necessary to introduce a vector, a method for introducing a vector may be any method so long as the method can introduce a DNA into a cell. Such a method includes transfection, transduction, transformation, and the like (for example, electroporation methods, particle gun (gene gun) methods, or the like).

When a gene is mentioned herein, the term "vector" or "recombinant vector" refers to a vector capable of transferring a polynucleotide sequence of interest to a target cell. Such a vector includes those capable of self-replication or incorporation into a chromosome in a host cell (e.g., a prokaryotic cell, yeast, an animal cell, a plant cell, an insect cell, an individual animal, and an individual plant, etc.), or those containing a promoter at a site suitable for transcription of a polynucleotide of the present invention. Promoters may be those capable of enhancing expression in



a host cell such an *E.coli*, yeast or the like. These will include trp promoter (Ptrp), lac promoter (Plac), PL promoter, PR promoter, PSE promoter or and the like, promoters derived from *E.coli* and phages and the like, SPO1 promoter, SPO2 promoter, penP promoter and the like. Artificially modified promoters such as those having two Ptrp tandemly located (Ptrp x2), tac promoter, lacT7 promoter, letI promoter and the like may be used.

10

A vector suitable for cloning is referred to as "cloning vector". Such a cloning vector ordinarily contains a multiple cloning site containing a plurality of restriction sites. Restriction sites and multiple cloning sites are well known in the art and may be appropriately or optionally used depending on the purpose. The technology is described in references as described herein (e.g., Sambrook et al. (*supra*)). Such vectors include, for example, plasmids.

20

"Recombinant vectors" for prokaryotic cells include pBTrp2, pBTac1, pBTac2 (both available from Roche Molecular Biochemicals), pKK233-2 (Pharmacia), pSE280 (Invitrogen), pGEMEX-1 (Promega), pQE-8 (QIAGEN), pKYP10 (Japanese Laid-Open Publication No.: 58-110600), pKYP200 (Agric.Biol.Chem., 48, 669 (1984)), pLSA1 (Agric.Biol.Chem., 53, 277 (1989)), pGEL1 (Proc.Natl.Acad.Sci.USA, 82, 4306 (1985)), pBluescript II SK+ (Stratagene), pBluescript II SK(-) (Stratagene), pTrs30 (FERM BP-5407), pTrs32 (FERM BP-5408), pGHA2 (FERM BP-400), pGKA2 (FERM B-6798), pTerm2 (Japanese Laid-Open Publication No.: 3-22979, US4686191, US4939094, US5160735), pEG400

30



(J.Bacteriol.,172,2392(1990)), pGEX (Pharmacia), pET systems (Novagen), pSupex, pUB110, pTP5, pC194, pTrxFus (Invitrogen), pMAL-c2 (New England Biolabs), pUC19 (Gene,33,103(1985)), pSTV28 (TaKaRa), pUC118 (TaKaRa),  
5 pPA1 (Japanese Laid-Open Publication No.: 63-233798), and the like.

"Recombinant vectors" for yeast cells include YEpl3 (ATCC37115), YEpl24 (ATCC37051), YCp50 (ATCC37419),  
10 pHS19, pHS15 and the like.

"Recombinant vectors" for animal cells include pcDNA1/Amp, pcDNA1, pCDM8 (all from available from Funakoshi), pAGE107 (Japanese Laid-Open Publication No.:  
15 3-229) (Invitrogen), pAGE103 (J.Biochem.,101,1307(1987)), pAMo, pAMoA (J. Biol. Chem., 268, 22782-22787(1993)) and the like.

Exemplary "recombinant vectors" for plant cells  
20 include Ti plasmid, tobacco mosaic virus vector and the like.

Exemplary "recombinant vectors" for insect cells include pVL1392, pVL1393, pBlueBacIII (all available  
25 from Invitrogen) and the like.

As used herein, the term "transformant" refers to the whole or a part of an organism, such as a cell, which is produced by transformation. Examples of a  
30 transformant include a prokaryotic cell, yeast, an animal cell, a plant cell, an insect cell, and the like. Transformants may be referred to as transformed cells, transformed tissue, transformed hosts, or the like, de-



pending on the subject.

When a prokaryotic cell is used herein for genetic operations or the like, the prokaryotic cell may be of, for example, the genus *Escherichia*, the genus *Serratia*, the genus *Bacillus*, the genus *Brevibacterium*, the genus *Corynebacterium*, the genus *Microbacterium*, the genus *Pseudomonas*, or the like. Specifically, the prokaryotic cell is, for example, *Escherichia coli* XL1-Blue, *Escherichia coli* XL2-Blue, *Escherichia coli* DH1, *Escherichia coli* MC1000, *Escherichia coli* KY3276, *Escherichia coli* W1485, *Escherichia coli* JM109, *Escherichia coli* HB101, *Escherichia coli* No.49, *Escherichia coli* W3110, *Escherichia coli* NY49, *Escherichia coli* BL21(DE3), *Escherichia coli* BL21(DE3)pLysS, *Escherichia coli* HMS174(DE3), *Escherichia coli* HMS174(DE3)pLysS, *Serratia ficaria*, *Serratia fonticola*, *Serratia liquefaciens*, *Serratia marcescens*, *Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Brevibacterium ammoniagenes*, *Brevibacterium immariophilum* ATCC14068, *Brevibacterium saccharolyticum* ATCC14066, *Corynebacterium glutamicum* ATCC13032, *Corynebacterium glutamicum* ATCC14067, *Corynebacterium glutamicum* ATCC13869, *Corynebacterium acetoacidophilum* ATCC13870, *Microbacterium ammoniaphilum* ATCC15354, *Pseudomonas* sp. D-0110 or the like.

When a yeast cell is used herein, such a cell includes yeast cells belonging to the genus *Saccharomyces*, genus *Schizosaccharomyces*, the genus *Kluyveromyces*, the genus *Trichosporonm*, the genus *Schwanniomyces*, and specifically include, for example, *Saccharomyces cerevisiae*, *Schizosaccharomyces pombe*, *Kluyveromyces lactis*,



*Trichosporon pullulans*, *Schwanniomyces alluvius*, *Pichia pastoris* and the like. A method for introducing such a recombinant vector may be any method for introducing DNA into a yeast, and includes electroporation methods  
5 [Methods.Enzymol.,194,182(1990)], spheroplast methods [Proc.Natl.Acad.Sci.USA,84,1929(1978)], lithium acetate methods [J.Bacteriol.,153,163(1983)], a method described in Proc.Natl.Acad.Sci.USA,75,1929(1978) and the like.

10

Examples of an animal cell as used herein includes a mouse myeloma cell, a rat myeloma cell, a mouse hybridoma cell, a Chinese hamster ovary (CHO) cell, a baby hamster kidney (BHK) cell, an African  
15 green monkey kidney cell, a human leukemic cell, HBT5637 (Japanese Laid-Open Publication No. 63-299), a human colon cancer cell line, and the like. The mouse myeloma cells include ps20, NSO, and the like. The rat myeloma cells include YB2/0 and the like. Human embryo  
20 kidney cells include HEK293 (ATCC:CRL-1573) and the like. The human leukemic cells include BALL-1 and the like. The African green monkey kidney cells include COS-1, COS-7, and the like. The human colon cancer cell lines include HCT-15, and the like.

25

Plant cells include those of potato, tobacco, maize, rice, oilseed, soybean, tomato, carrot, wheat, barley, rye, alfalfa, linum and the like. A method for introducing such an expression vector may be any method  
30 for introducing DNA into a plant cell, and include, for example, Agrobacterium methods (Japanese Laid-Open Publication Nos.: 59-140885, 60-70080, WO 94/00977), electroporation methods (Japanese Laid-Open Publication



No.: 60-251887), particle gun (gene gun) methods (Japanese Patent Nos. 2606856 and 2517813) and the like.

5 An insect cell includes a cultured cell derived from ovarian cells of *Spodoptera frugiperda*, or *Bombyx mori* ovary. *Spodoptera frugiperda* ovarian cells include Sf9, Sf21 (Baculovirus Expression Expression Vectors: A Laboratory Manual) or the like, *Trichoplusia ni* ovarian cells include High 5, BTI-TN-5B1-4 (Invitrogen) or the  
10 like, cultured cells derived from *Bombyx mori* ovary include as an example *Bombyx mori* N4.

A method for producing a polypeptide or the salt thereof can employ any well known technology in the art  
15 and include for example, a method wherein a transformant such as prokaryotic cell, yeast cell, animal cell, plant cell, insect cell and the like including a recombinant vector with a DNA encoding the polypeptide of the present invention incorporated therein is cultured  
20 according to an ordinary culture method, the polypeptide of the present invention is produced and accumulated, and the polypeptide of the present invention is obtained from the culture to produce the polypeptide of the present invention.

25

As used herein, the term "antibody" is used in its ordinary sense, which is well known to those skilled in the art. As used herein, the term "antibody" encompasses the whole molecule and a fragment thereof,  
30 a derivative thereof, a conjugate thereof, and the like. Preferably, antibodies, which are preferably used in the present invention, recognize a polypeptide of the present invention, more preferably in a specific manner.



Such antibodies may be polyclonal antibodies or monoclonal antibodies.

5 The cell or cell composition prepared by using  
the agent of the present invention can be provided in  
any formulation format so long as the format is appropriate for introduction into the living organism. Such  
a formulation format includes for example a liquid  
agent, an injection agent, a sustained release agent or  
10 the like. Administration routes include oral administration, parental administration, direct administration to a diseased site, and the like

Injection drugs can be prepared using techniques  
15 well known in the art. For example, an agent of the present invention is dissolved in an appropriate solvent (physiological saline, buffer (e.g., PBS, etc.), sterilized water, etc.), followed by filter sterilization using a filter, or the like. Thereafter, the solution is placed into a sterile container (e.g., an ampoule, or the like). Thus, an injection drug can be prepared. The injection drug may contain a commonly used pharmaceutical carrier if required. An administration method using a non-invasive catheter may be employed.  
25

In one embodiment, an agent of the present invention may be provided in a sustained-release form. When administered in a sustained-release form, an active  
30 component (e.g., a nucleic acid or a polypeptide) is effective if efficacy thereof can be expected over a long time due to sustained release. Any sustained-released dosage form may be used in the present invention.



tion. Examples of sustained-release dosage forms include, but are not limited to, rod-like formulations (e.g., pellet-like, cylinder-like, needle-like formulations, etc.), tablet formulations, disk-like formulations, sphere-like formulations, sheet-like formulations, and the like. Methods for preparing sustained-release dosage forms are well known in the art, as described in, for example, the Japanese Pharmacopeia, the U.S. Pharmacopeia, Pharmacopeias of other countries, and the like. Examples of a method for producing sustained-release drugs include, but are not limited to, a method using disaggregation of a drug from a complex, a method for preparing an aqueous suspended liquid drug, a method for preparing an oil injection liquid or oil suspended injection liquid, a method for preparing an emulsified injection liquid (o/w or w/o type emulsified injection liquid, or the like), and the like.

As used herein, polypeptide expression may be "detected" or "quantified" by an appropriate method, including mRNA measurement and immunological measurement methods. Examples of the molecular biological measurement methods include a Northern blotting method, a dot blotting method, a PCR method, and the like. Examples of the immunological measurement method include an ELISA method, an RIA method, a fluorescent antibody method, a Western blotting method, an immunohistological staining method, and the like, where a microtiter plate may be used. Examples of a quantification method include an ELISA method, an RIA method, and the like.

As used herein, the term "amount of expression" refers to the amount of a polypeptide or mRNA expressed



in a cell of interest or the like. The amount of expression includes the amount of expression at the protein level of a polypeptide of the present invention evaluated by any appropriate method using an antibody of the present invention, including immunological measurement methods (e.g., an ELISA method, a RIA method, a fluorescent antibody method, a Western blotting method, an immunohistological staining method, and the like, or the amount of expression at the mRNA level of a polypeptide of the present invention evaluated by any appropriate method, including molecular biological measurement methods (e.g., a Northern blotting method, a dot blotting method, a PCR method, and the like). The term "change in the amount of expression" indicates an increase or decrease in the amount of expression at the protein or mRNA level of a polypeptide of the present invention evaluated by an appropriate method including the above-described immunological measurement method or molecular biological measurement method.

20

#### BEST MODE FOR CARRYING OUT THE INVENTION

In one aspect, the present invention provides a polypeptide having a WIF domain which maintains pluripotency without differentiating a stem cell. As used herein, the "maintenance of undifferentiation (or without or no differentiation)" refers to maintaining an undifferentiated state or not making differentiated. Therefore, no differentiation and maintaining undifferentiated as well as suppressing differentiation are used herein to have the same meaning. Further, no differentiation refers to a state in which each of cells or cell groups in the early developing period of an organism cannot be distinguished from a morphological or

30



functional point of view.

In one embodiment, the polypeptide of the present invention is WIF-1. WIF-1 preferably comprises a sequence set forth in SEQ ID NOS: 2 (murine), 4 (human), 5 6 (rat), 8 (*Xenopus*) or 10 (Zebrafish). More preferably, the polypeptide of the present invention comprises a sequence set forth in SEQ ID NO: 4 or a variant sequence thereof. Still more preferably, the polypeptide 10 of the present invention comprises a sequence set forth in SEQ ID NO: 4. WIF-1 is an abbreviation of Wnt inhibitory factor-1, and was reported in 1999 as a novel protein binding to Wnt protein and inhibiting the activity thereof (Hsieh J.H., et al., *Nature* 398, 431-436, 15 1999). Hsieh et al., identified the gene product of WIF-1 and the expression pattern in human, mouse, *Xenopus* and Zebrafish, and proved the *in vitro* inhibitory activity of a Wnt protein. Hsieh et al., further reported that WIF-1 inhibited body segmentation and 20 axis formation activity in *Xenopus*.

Wnt is known to be an agent controlling embryonic body axis formation and organ formation (Cadigan K.M., and Nusse R., *Genes & Development* 11:3286-3305). Wnt 25 was found in separate studies in mouse (originally called as int-1), insect (*Drosophila*; originally called wg (wingless)) and later found in other organisms such as *Caenorhabditis elegans*, a wide range of vertebrates including mammals including humans, amphibians and the 30 like. However, Wnt has about 20 kinds of homologs such as Wnt-1, and there are a number of functions for the homologs. Some Wnt are believed to mediate stabilization of beta-catenin in cytoplasm and the gene expres-



sion associated thereof, however, there are also other types of Wnt suggested to be involved in cancer formation. As such, the Wnt family as a whole is chaotic with respect to the functions thereof. As a protein interacting with Wnt, Fz (Frizzled) receptor is known, however, a number of functions are reported for the receptor and are not yet clarified.

Thus, WIF-1 was isolated as a factor having Wnt-inhibitory activity, however, the activity thereof has been unknown up to date. As WIF-1 has an EGF-like repeat as apparent from the sequence thereof, in the present invention the differentiation regulation activity of such an EGF-like repeat is noted. In another aspect, it is also noted that the WIF domain corresponds to about position 30 to about 180 of the amino acid sequence of mouse WIF-1 with respect to the differentiation regulation function thereof. In the present invention, it has been clarified that a protein having a WIF-domain optionally having an EGF-like repeat, has a function of expanding a cell while maintaining its pluripotency without differentiation optionally in the presence of an essential factor for survival such as SCF. Accordingly, in a preferable embodiment, the present polypeptide has a WIF domain and an EGF-like repeat. In another embodiment, the present polypeptide may be a different polypeptide having a EGF-like repeat. It has not been reported that a polypeptide having an EGF-like repeat has an activity suppressing differentiation without losing pluripotency of a hematopoietic stem cell. Therefore, by the present invention, it is surprising that a large volume of culture of hematopoietic stem cells, which are clinically applicable, has



been achieved. Thus, in a preferable embodiment, a stem cell used in the present invention may be a hematopoietic stem cell.

5           The following methods may also be considered for cloning a gene of WIF-1. As WIF-1 has been found in a variety of organisms, it is considered that a portion of the amino acid sequence thereof is conserved in the process of evolution of living organisms. Accordingly,  
10 a DNA sequence corresponding to a conserved amino acid sequence (for example, a WIF domain or an EGF-like domain or the like) is designed for use as a primer in a RT-PCR (reverse transcription polymerase chain reaction) and proliferation of an equivalent of another  
15 living organism corresponding to the polypeptide of the present invention, may be obtained. Accordingly, such an equivalent is also within the scope of the present invention. Further, a sequence obtained by conducting a homology search against genome databases such as the  
20 human genome project, or gene information databases such as GenBank or the like using software such as BLAST, is also within the scope of the present invention.

25           A sequence obtained by screening a cDNA library of an organ using a fragment found in such an homology search as a probe to clone genes having a longer gene sequence, or full-length genes, is also within the scope of the present invention. Such a screening method  
30 includes a method using a radioisotope or not. Further, a method without using a library such as 5'-RACE, 3'-RACE or the like may be used. In another embodiment, a stem cell transformed with a vector containing a nu-



cleic acid encoding a polypeptide according to the present invention is provided.

In another aspect, the present invention provides  
5 a composition for maintaining a pluripotency of a stem cell with maintaining an undifferentiated state thereof. The present composition includes a polypeptide having a WIF domain. A composition according to the present invention optionally comprises a stem cell survival agent.  
10 As used herein, the term "stem cell survival agent" is an agent considered to be essential for survival of a stem cell. Conventionally, the survival (and differentiation) of stem cells has been thought to require SCF. However, Ornitz M., et al. (Immunity, Vol. 10, 173-182, 1999)  
15 discovered a pluripotent hematopoietic stem cell which does not express c-Kit which is a receptor to SCF. Therefore, SCF *per se* is not required for survival of all the stem cells. Further, SCF *per se* has no differentiation activity. Accordingly, a stem cell used  
20 herein may be propagated with maintenance of the undifferentiated state thereof and preserving the pluripotency thereof in the presence of a polypeptide having a WIF domain so long as the cell is in the circumstances enabling the survival thereof. Usually, a stem cell requires SCF as described above, preferably a stem cell  
25 propagates with maintenance of the undifferentiated state thereof and preserving the pluripotency thereof, in the presence of a polypeptide having a WIF domain (for example, WIF-1) and SCF. Accordingly, in a preferable embodiment, the above-described stem cell survival  
30 agent is SCF. In the presence of SCF alone, as shown in the Examples herein, it has been clarified that a stem cell gradually loses the pluripotency thereof although



maintains the survival thereof.

In another aspect, the present invention provides a stem cell maintaining an undifferentiated state and having a pluripotency *in vitro*. In a preferable embodiment, the cell of the present invention is a hematopoietic stem cell. Preferably, the stem cell of the present invention having pluripotency with maintenance of the undifferentiated state thereof *in vitro*, preserves its pluripotency for at least three days or at least five days, preferably at least six days, more preferably at least ten days, still more preferably, at least twenty days, thirty days, two months, three months, six months, one year. Naturally, there is a fresh stem cell (for example, a hematopoietic stem cell) as a stem cell without differentiation and such stem cells preserve pluripotency. However, in the absence of an agent of the present invention, such a stem cell immediately differentiates or dies. Therefore, the fact that a stem cell can maintain an undifferentiated state for a long period of time as mentioned above (for example, days to years), is a significant effect which cannot be achieved by the conventional technology. It is also a significant effect that the function of a stem cell just after its isolation from the host thereof can be preserved for a long period of time, which cannot be attained by conventional methods. As used herein, a period for preserving pluripotency refers to a period until the differentiation of the cell is determined for a certain direction. The determination whether or not differentiation has been taken place can be easily conducted by any of a variety of known methods, and such a method includes for example, colony assay. In an em-



bodiment, when the determination is conducted by a colony assay, a stem cell isolated *in vitro* according to the present invention, preserves its pluripotency for at least fourteen days.

5

In a preferable embodiment, the pluripotency which a cell according to the present invention, comprises includes the capability of differentiation into the blood cells.

10

In another aspect, the present invention provides a long period pluripotency maintaining cell composition. As used herein the term "long period pluripotency maintaining cell composition" refers to a composition comprising a cell which is preferably a stem cell, and holds its pluripotency and does not differentiate for a long period of time (for example, at least three days, preferably at least five days, more preferably, at least ten days, still more preferably at least twenty days, thirty days, two months, three months, six months, and one year). The long period pluripotency maintaining cell composition comprises a stem cell and a polypeptide having a WIF domain.

25

In one embodiment of the present invention, the above-mentioned stem cell may be a hematopoietic stem cell. In another embodiment, the above-mentioned stem cell may be another tissue stem cell. In another embodiment, the above-mentioned stem cell may be an embryonic stem cell.

30

Preferably, in the present composition, a stem cell is present at least at  $10^3$  cells, preferably at



least at  $2 \times 10^3$  cells, at least at  $5 \times 10^3$  cells, at  
least at  $10^4$  cells, at least at  $2 \times 10^4$  cells, at least  
at  $5 \times 10^4$  cells, at least at  $2 \times 10^5$  cells, at least at  
5  $5 \times 10^5$  cells, at least at  $10^6$  cells, at least at  $2 \times$   
10  $10^6$  cells, at least at  $5 \times 10^6$  cells, at least at  $10^7$   
cells, at least at  $2 \times 10^7$  cells, at least at  $5 \times 10^7$   
cells, at least at  $10^8$  cells, at least at  $2 \times 10^8$  cells,  
at least at  $5 \times 10^8$  cells, at least at  $10^9$  cells, at  
least at  $2 \times 10^9$  cells, at least at  $5 \times 10^9$  cells, at  
10 least at  $10^{10}$  cells, or more than at least at  $10^{10}$  cells.  
An appropriate amount will vary depending on the cir-  
cumstances used, and those skilled in the art can ap-  
propriately determine such an amount depending on the  
condition of the agent used present in the composition  
15 used, and when used as a medicament, the condition of a  
patient, the condition of the diseases of the patient,  
the route of administration, the form of administration  
and the like.

20 In a preferable embodiment, the above-mentioned  
polypeptide having a WIF domain may be WIF-1 (for exam-  
ple, comprising a sequence set forth in SEQ ID Nos: 2,  
4, 6, 8 or 10). In a different preferable embodiment,  
the polypeptide of the present invention may be a poly-  
25 peptide having an EGF-like repeat and such a polypep-  
tide includes a member of the notch family protein  
(such as notch-1, notch-2, jagged-1, Dll-1, DLK or the  
like). The polypeptide of the present invention or the  
polypeptide used in the present invention may be a  
30 polypeptide of the natural form, and may be a recombi-  
nantly produced polypeptide, a synthetic polypeptide or  
a variant thereof so long as it is functionally equiva-  
lent thereto. The polypeptide of the present invention



may be provided to a stem cell in a form of a nucleic acid. In this case, the stem cell may be transformed with a nucleic acid molecule containing a nucleic acid sequence encoding the polypeptide of the present invention. Methods for transformation are well known in the art and described in detail elsewhere in the present specification. Accordingly, those skilled in the art can conduct such transformations according to the teaching of the present specification.

10

In a preferable embodiment, the above-described polypeptide can be present at least at 0.1 ng/ml. More preferably, the polypeptide may be present at least at 1.0 ng/ml, at least at 2.0 ng/ml, at least at 5.0 ng/ml, at least at 20.0 ng/ml, at least at 50.0 ng/ml, at least at 100.0 ng/ml, at least at 200.0 ng/ml, at least at 500.0 ng/ml, at least at 1.0 µg/ml, at least at 2.0 µg/ml, at least at 10.0 µg/ml, at least at 100.0 µg/ml or at least more than at 1 mg/ml.

20

In a preferable embodiment, the composition of the present invention further comprises a stem cell survival agent. Preferably, the stem cell survival agent may be SCF. The activity for maintaining pluripotency with an undifferentiated state is augmented by the coexistence of such a stem cell survival agent in addition to the polypeptide of the present invention.

25

In a preferable embodiment, the above-described stem cell survival agent (for example, SCF) may be present at least at 0.1 ng/ml. More preferably, the stem cell survival agent (for example, SCF) may be present at least at 1.0 ng/ml, at least at 2.0 ng/ml, at least

30



at 5.0 ng/ml, at least at 20.0 ng/ml, at least at 50.0 ng/ml, at least 100.0 ng/ml, at least 200.0 ng/ml, at least t 500.0 ng/ml, at least at 1.0 µg/ml, at least at 2.0 µg/ml, at least at 10.0 µg/ml, at least at 100.0 µg/ml or at least at more than 1 mg/ml.

10 In another preferable embodiment, the stem cell survival agent may be the TPO. The activity for maintaining pluripotency with an undifferentiated state may be augmented by the coexistence of the TPO in addition to the polypeptide of the present invention. The TPO may augment the activity of maintaining pluripotency with undifferentiated state by the addition thereof in addition to the SCF and/or FL.

15

In a preferable embodiment, TPO may be present at least at 1.0 ng/ml, at least at 2.0 ng /ml, at least at 5.0 ng /ml, at least at 20.0 ng /ml, at least at 50.0 ng/ml, at least at 100.0 ng/ml, at least at 200.0 ng/ml, 20 at least at 500.0 ng/ml, at least at 1.0 µg/ml, at least at 2.0 µg/ml, at least at 10.0 µg/ml, at least at 100.0 µg/ml or at least more than at 1 mg/ml.

25 In another preferable embodiment, the stem cell survival agent may be flt-3 ligand (FL). More preferably, the activity for maintaining pluripotency with an undifferentiated state is augmented by the coexistence of a plurality of stem cell survival agents (for example, at least two, preferably three of SCF, TPO and FL 30 and the like) in addition to the polypeptide of the present invention.

In a preferable embodiment, FL may be present at



least at 0.1 ng/ml. More preferably, FL may be present  
1.0 ng/ml, at least at 2.0 ng/ml, at least at 5.0 ng/ml,  
at least at 20.0 ng/ml, at least at 50.0 ng/ml, at  
least at 100.0 ng/ml, at least at 200.0 ng/ml, at least  
5 at 500.0 ng/ml, at least at 1.0 µg/ml, at least at 2.0  
µg/ml, at least at 10.0 µg/ml, at least at 100.0 µg/ml  
or at least at more than at 1 mg/ml.

In a preferable embodiment, the present invention  
10 provides a composition for preparing differentiated  
cells. The differentiated cells may be used for treat-  
ing disorders of the blood cells. A method for prepar-  
ing differentiated cells from a stem cell is well known  
in the art, and includes for example, a method for add-  
15 ing a hematopoietic factor and the like.

In another aspect, the present invention provides  
a method for maintaining pluripotency without differen-  
tiating a stem cell. The method comprises 1) providing  
20 the stem cell with a polypeptide having a WIF domain.

In an embodiment of a method for maintaining  
pluripotency of a stem cell of the present invention,  
the above-described specific elements to be used in  
25 preferable embodiments of the above-described composi-  
tion, may be the specific elements of the method of the  
present invention.

In one embodiment of the present invention, the  
30 above-described polypeptide having a WIF domain (for  
example, WIF-1 such as those polypeptides comprising a  
sequence set forth in SEQ ID NO: 2, 4, 6, 8 or 10) may  
be provided in the form of a polypeptide. In another



embodiment, the polypeptide may be provided in the form of a nucleic acid. In the case where provided in the form of a nucleic acid, the method of the present invention further comprises the step of transforming the stem cell with a nucleic acid comprising a nucleic acid sequence encoding the polypeptide.

In another embodiment of the present invention, the method of the present invention further comprises the step of providing a stem cell survival agent (for example, SCF) to the stem cell. The stem cell survival agent may be provided before, after or at the same time of the provision of the polypeptide having a WIF domain. The stem cell survival agent may be directly provided in the form of polypeptide. In another embodiment, the stem cell survival agent may be provided in the form of a nucleic acid. In the case where provided in the form of a nucleic acid, the method of the present invention further comprises the step of transforming the stem cell with a nucleic acid molecule comprising a nucleic acid sequence encoding the stem cell survival agent.

In another aspect, the present invention provides a method for producing a long period pluripotency maintaining cell composition. The present method comprises 1) providing a stem cell; 2) providing the stem cell with a polypeptide having a WIF domain; and 3) collecting the stem cell treated.

In embodiments of the method for producing a long period pluripotency maintaining cell composition, the above-described specific elements to be used in preferable embodiments of the above-described composition,



may be the specific elements of the method of the present invention.

5 In an embodiment of the present invention, the polypeptides having a WIF domain (for example, WIF-1) may be directly provided in the form of a polypeptide. In another embodiment, the polypeptide may be in the form of a nucleic acid. In the case where provided in the form of a nucleic acid, the production method of  
10 the present invention further comprises the step of transforming the stem cell comprising a nucleic acid molecule comprising a nucleic acid sequence encoding the polypeptide.

15 In another embodiment of the present invention, the production method of the present invention further comprises the step of providing a stem cell survival agent (for example, SCF) to the stem cell. The stem cell survival agent is provided before, after or at the  
20 same time as the provision of the polypeptide having a WIF domain. The stem cell survival agent may be directly provided in the form of a polypeptide. In another embodiment, the stem cell survival agent may be provided in the form of a nucleic acid. In the case  
25 where provided in the form of a nucleic acid, the production method of the present invention further comprises the step of transforming the stem cell with a nucleic acid molecule comprising a nucleic acid sequence encoding the stem cell survival agent. The tech-  
30 nology such as transformation and the like are well known in the art and described elsewhere herein.

In another aspect, the present invention provides



a method for producing differentiated cells in a large scale. The method comprises the steps of 1) providing a stem cell; 2) providing a polypeptide having a WIF domain to the stem cell; 3) collecting the thus treated  
5 stem cells; and 4) providing a differentiation factor to the stem cell.

In an embodiment of a method for producing differentiated cells in a large scale of the present invention,  
10 the above-described specific elements to be used in preferable embodiments of the above-described composition, may be the specific elements of the method of the present invention.

15 In another embodiment, the polypeptide having a WIF domain (for example, WIF-1) may be directly provided in the form of polypeptide. In another embodiment, the polypeptide may be provided in the form of a nucleic acid. The differentiation factor may also be provided  
20 in the form of polypeptide or nucleic acid. In the case where provided in the form of nucleic acid, a vector construct may be constructed so that the differentiation factor is expressed later than the polypeptide of the present invention and the stem cell may be  
25 transformed with the construct. A method for producing and transforming such a vector construct is well known in the art and those skilled in the art can readily carry out such a method based on the teachings of the present application.

30

In another embodiment of the present invention, the production method of the present invention further comprises the step of providing the stem cell with a



stem cell survival agent (for example, SCF). The stem cell survival agent may be provided before, after or at the same time of the provision of the polypeptide having a WIF domain. The stem cell survival agent may be  
5 directly provided in the form of polypeptide. In another embodiment, the stem cell survival agent may be provided in the form of a nucleic acid. In the case where provided in the form of a nucleic acid, the production method of the present invention further com-  
10 prises the step of transforming the stem cell with a nucleic acid molecule comprising a nucleic acid sequence encoding the stem cell survival agent. Technology such as transformation is well known in the art and described elsewhere herein. In one embodiment, nu-  
15 cleic acid sequences encoding the present polypeptide and the stem cell survival agent may be engineered so as to reduce or stop the expression after a certain period of time. In such a case, a differentiation factor may be engineered to be expressed after a certain pe-  
20 riod of time.

In another aspect, the present invention provides a method for treating a disease or disorder derived from a disorder of differentiated cells. The method  
25 comprises the steps of 1) administering a long period pluripotency maintaining cell composition comprising a stem cell and a polypeptide having a WIF domain. The administration method may be any method well known in the art. Administration methods may herein include oral  
30 administration and parenteral administration (e.g., intravenous, intramuscular, subcutaneous, intradermal, mucosal, intrarectal, intravaginal, topical to an affected site, to the skin, etc.), direct administration



to affected portions, and the like. A prescription for such administration may be provided in any formulation form. Such formulation forms include liquid formulations, injections, sustained preparations, and the like.

- 5 Preferably, the polypeptide having a WIF domain may include a sequence set forth in SEQ ID NO: 4 or a variant sequence thereof, and preferably may be human recombinant WIF-1.

- 10 In an embodiment of a method for treating a disease or disorder derived from the disorder of a differentiated cell of the present invention, the above-described features in preferable embodiments for the above-described composition are also applicable for the  
15 specific features of the method of the present invention.

- In another aspect, the present invention provides a method for treating a disease or disorder derived  
20 from a disorder of a differentiated cell. The method comprises a step of 1) administering a differentiated cell prepared from a stem cell processed with a polypeptide of the present invention, to a subject. Any well known method for administration in the art may be  
25 used for this method. Administration methods include: oral administration, parenteral administration (such as intravenous administration, intramuscular administration, subcutaneous administration, intradermal administration, mucous administration, intrarectal administration,  
30 stration, intravaginal administration, direct administration to a diseased site, skill administration etc). A formulation for such an administration may be provided in any formulation form. Such formulation formats



include for example, liquid agents, injections, sustained-release agents and the like.

5 In an embodiment of a method for treating a disease or disorder derived from a disorder of a differentiated cell (for example, the blood cells) of the present invention, the above-described specific elements to be used in preferable embodiments of the above-described composition, may be the specific elements of  
10 the method of the present invention.

The method for treatment of the present invention can be used for any living organism such as vertebrates or invertebrates so long as the living organism can be  
15 subject to a disease or a disorder derived from a differentiated cell. In a preferable embodiment, such a living organism may be vertebrate, more preferably, such a living organism may be a mammal (for example, rodent and the like), and still more preferably may be  
20 primates, and most preferably may be a human.

Preparation protocols for preparing such a formulation are known in the art and described in for example, Japanese Pharmacopoeia, U.S. Pharmacopoeia, and  
25 pharmacopoeia of the other countries, and the like. Accordingly, based on the description of the present specification, those skilled in the art can determine the amounts of polypeptides and cells to be administered without undue experimentation.

30

Injection drugs can be prepared using techniques well known in the art. For example, an agent of the present invention is dissolved in an appropriate sol-



vent (physiological saline, buffer (e.g., PBS, etc.), sterilized water, etc.), followed by filter sterilization using a filter, or the like. Thereafter, the solution is placed into a sterile container (e.g., an ampoule, or the like). Thus, an injection drug can be prepared.

The diseases or disorders which can be treated by the present invention may be those related to disorders of differentiated cells into which the stem cells used in the present invention can differentiate. In a preferable embodiment, such a differentiated cell may be blood cells. Examples of the diseases or disorders include, but are not limited to, anemia (e.g., aplastic anemia (particularly, severe aplastic anemia), renal anemia, cancerous anemia, secondary anemia, refractory anemia, etc.), cancer or tumors (e.g., leukemia); and after chemotherapy therefor, hematopoietic failure, thrombocytopenia, acute myelocytic leukemia (particularly, a first remission (high-risk group), a second remission and thereafter), acute lymphocytic leukemia (particularly, a first remission, a second remission and thereafter), chronic myelocytic leukemia (particularly, chronic period, transmigration period), malignant lymphoma (particularly, a first remission (high-risk group), a second remission and thereafter), multiple myeloma (particularly, an early period after the onset), neutropenia and the like. In a preferable embodiment, the diseases or disorders, which can be treated according to the present invention, may be human diseases or disorders.

By the stem cells of the present invention, a



number of side effects associated with conventional hematopoietic cell transplantation therapy derived from natural sources (particularly, those associated with foreign substances or foreign cells, such as infection, graft-versus-host disease, and the like) are avoided. This effect is first attained by the present invention in which a technology for maintaining pluripotency of a cell with maintaining an undifferentiated state, and therefore should be noted to be surprising. Further, by maintaining pluripotency of stem cells with an undifferentiated state for a long period of time, it is now possible to produce pluripotent stem cells in a large-scale. In addition, it is also now possible to prepare a large number of differentiated cells from such a large number of stem cells cultured in a large scale. Such effects cannot be attained by the conventional methods, and should be noted to be significant.

In another embodiment, the treatment method of the present invention may further comprise a step of administering another drug. Such another drug may be any drug known in the art, and formulations thereof include for example, any formulation known in the pharmaceutical field including antibiotics. Naturally, such drugs may include two or more other drugs. Such drugs include for example those listed in Japanese pharmacopoeia the latest version, the United States pharmacopoeia the latest version, or other country's pharmacopoeia the latest version or the like. Such drugs may preferably be those having effects on the hematopoietic system.

In other embodiment, the above-mentioned cells



may include two or more kinds of cells. When two or more kinds of cells are used, cells having identical or similar properties or origin, or different properties or origin may be used.

5

The amount of an agent or cell used in the method of the present invention can be easily determined by those skilled in the art with reference to the purpose of use, the subject's age, size, sex, and case history,  
10 the form or type of agent or cell, and the like.

The frequency of the method of the present invention which is applied to a subject is also determined by those skilled in the art with respect to the purpose  
15 of use, the subject's age, size, sex, case history, the progression of the therapy, and the like. Examples of the frequency include once per day to once per several months (e.g., once per week to once per month). Preferably, administration is performed once per week to  
20 once per month with reference to the progression.

In another aspect, the present invention provides a pharmaceutical composition for treating a disease or disorder derived from disorders of differentiated cells.  
25 The pharmaceutical composition includes a stem cell; a polypeptide having a WIF domain; and a pharmaceutically acceptable carrier. Preferably, the polypeptide having a WIF-1 domain may include the sequence set forth in SEQ ID NO: 4 or a variant sequence thereof, and may be  
30 human recombinant WIF-1.

In one embodiment, the object disease or disorder of the pharmaceutical composition may be any one de-



scribed herein above.

In a variation of the embodiments of a pharmaceutical composition of the present invention, any specific elements to be applied in the preferable embodiments of the above-mentioned composition may be applied to the specific elements of the pharmaceutical composition of the present invention.

In another aspect, the present invention provides a pharmaceutical composition for treating a disease or disorder derived from a disorder of differentiated cells. The pharmaceutical composition comprises a differentiated cell prepared from a stem cell processed using a polypeptide of the present invention; and a pharmaceutically acceptable carrier.

In one embodiment, the objects of the present pharmaceutical composition are the same as described herein above.

In a variation of the embodiments of the present pharmaceutical composition, the particular elements in a number of preferable embodiments of the present composition can be applied to specific elements to be included in the pharmaceutical composition of the present invention.

Pharmaceutically acceptable carriers included in the pharmaceutical composition of the present invention include any material known in the art. Examples of such an appropriate materials or pharmaceutical acceptable agents include, but are not limited to, antioxidants,



preservatives, colorants, flavoring agents, diluents, emulsifiers, suspending agents, solvents, fillers, bulking agents, buffers, delivery vehicles, and/or pharmaceutical adjuvants. Representatively, a medication of the present invention is administered in the form of a composition comprising an active component of the present invention (e.g., a polypeptide, a nucleic acid, or the like) with at least one physiologically acceptable carrier, excipient or diluent. For example, an appropriate vehicle may be an injection solution, a physiological solution, or artificial cerebrospinal fluid, which can be supplemented with other substances which are commonly used for compositions for parenteral delivery.

15

Examples of appropriate carriers include neutral buffered saline or saline mixed with serum albumin. Preferably, the product is formulated as a lyophilizate using appropriate excipients (e.g., sucrose). Other standard carriers, diluents, and excipients may be included as desired. Other exemplary compositions comprise Tris buffer of about pH 7.0-8.5, or acetate buffer of about pH 4.0-5.5, which may further include sorbitol or a suitable substitute therefor. The pH of the solution or various other pH's should be selected based on the relative solubility of a polypeptide of the present invention.

Solvents for use in preparing a composition may be either aqueous or nonaqueous. Vehicles for the compositions may contain other components for modifying or maintaining pH, osmolarity, viscosity, transparency, color, sterility, stability, isotonicity, disintegra-

30



tion rate, or smell of the formulation. Similarly, a composition of the present invention may contain other components for modifying or maintaining the release rate of an effective component or absorption or permeability of an effective component.

A composition of the present invention may be parenterally administered. The composition may be intravenously or subcutaneously administered. When administered systemically, the therapeutic composition for use in the present invention may be in a form of an aqueous solution which is orally acceptable and pyrogen-free. The preparation of such pharmaceutically acceptable compositions, with due regard to pH, isotonicity, stability and the like, is within the skill of the art.

The therapeutic formulation of the present invention may be prepared for storage by mixing a selected composition having the desired degree of purity with optional physiologically acceptable carriers, excipients, or stabilizers (Japanese Pharmacopeia; Remington's Pharmaceutical Sciences, 18th Edition, A. R. Genaro, ed., Mack Publishing Company, 1990; and the like), in the form of lyophilized cake or aqueous solutions.

Acceptable carriers, excipients or stabilizers used herein preferably are nontoxic to recipients and are preferably inert at the dosages and concentrations employed, and preferably include phosphate, citrate, or other organic acids; antioxidants (e.g., ascorbic acid); low molecular weight polypeptides; proteins (e.g., serum albumin, gelatin, or immunoglobulins); hy-



drophilic polymers (e.g., polyvinylpyrrolidone); amino acids (e.g., glycine, glutamine, asparagine, arginine or lysine); monosaccharides, disaccharides, and other carbohydrates (glucose, mannose, or dextrans); chelating agents (e.g., EDTA); sugar alcohols (e.g., mannitol or sorbitol); salt-forming counterions (e.g., sodium); and/or nonionic surfactants (e.g., Tween, pluronics or polyethylene glycol (PEG)).

10 Cells, compositions or the like of the present invention can be used not only just after the preparation thereof, but also after storage for a certain period of time such as about one day, about two days, about three days, about four days, about five days, 15 about six days, about seven days, about two weeks, about three weeks, about four weeks, about two months, about three months, about four months, about five months, about six months, about one year or the like, under for example, about 4 degree Celcius, about -18 20 degree Celcius, about -70 degree Celcius, or under liquid nitrogen or the like.

Hereinafter, the present invention will be described by way of examples. Examples described below 25 are provided only for illustrative purposes. Accordingly, the scope of the present invention is not limited except as by the appended claims.

#### EXAMPLES

30

(Example 1: Recombinant WIF-1 preparation)

1.

PA-6 cell line was kindly provided from Dr. Hiro-



shi KODAMA at Ōu University and was cultured in Minimum Essential Medium Alpha Medium ( $\alpha$ -MEM) (Sigma, St. Louis, USA) with 10 % fetal calf serum added at 37 °C under 5% CO<sub>2</sub> until confluent.

5

PA-6 cells were collected and the mRNA thereof was isolated using a QuickPrep mRNA purification kit (Amersham Pharmacia Biotech, Uppsala, Sweden) and thus cDNA was synthesized using SuperScript® RnaseH-reverse transcriptase (Invitrogen, Groningen, The Netherlands) for use in degenerate PCR.

From the conservative sequences of EGF-like repeats of the Notch family, degenerate primers of SEQ ID Nos: 11 and 12 were synthesized and a partial sequence of the WIF-1 gene was isolated under the following conditions:

a) Reaction Mixture

Primers (SEQ ID Nos: 11 and 12) 10  $\mu$ M each; cDNA 1,500 ng/ml; dNTPs 0.25mM each; polymerase, 0.5 U/ml (TakaraTag, TaKaRa, Shiga, Japan); buffer: 0.15m M MgCl<sub>2</sub>, 10mM Tris-HCl (pH 8.3), 50 mM KCl.

b) Reaction cycle

- (i) 94 °C, 60 seconds, 1 cycle;
- (ii) 94 °C, 20 seconds; 60 °C, 20 seconds; 72 °C, 20 seconds; 30 cycles;
- (iii) 72 °C, three minutes, 1 cycle.

After gel electrophoresis of the reaction products, a nucleic acid fragment having about 180 bp was collected and sequenced to confirm that the fragment was a fragment derived from the WIF-1 gene.



This fragment was used as a hybridization probe to isolate a full-length clone of the WIF-1 from Mouse Day15 Embryo 5'-Stretch Plus cDNA Library (Clontech, Palo Alto, California, USA). The sequences thereof are shown in SEQ ID NO: 1 (nucleic acid) and SEQ ID NO:2 (amino acid sequence).

(2. Expression and Purification of Recombinant WIF-1)

The full-length clone of the WIF-1 as isolated in 1. above, as digested with restriction enzymes XhoI and NheI and the resultant fragment was ligated to the pCAGGS-6His vector, in which a 6-His sequence having restriction sites in the pCAGGS vector provided from Dr. Jun-ichi MIYAZAKI, Kumamoto University, was inserted, (SEQ ID NO: 13), and this vector was designated as pCAGGS/mWIF-1-6His.

The pCAGGS/mWIF-1-6His was transduced into COS7 cells by the calcium phosphate method, and the cells were cultured in DMEM (Dulbecco's Modified Eagle Medium) supplemented with 10 % FCS, under 5% CO<sub>2</sub>, at 37 °C until confluent.

A recombinant WIF-1 was purified from the transduced COS7 cells using the following methods. The culture supernatant was passed through a Nickel-column (His Trap, Amersham Pharmacia Biotech), and thus mWIF-1 was bound to the column. In order to remove non-specific bound proteins, the column was washed well with phosphate buffer with 100 mM imidazole added, and then mWIF-1-6His was eluted with a phosphate buffer with 300 mM imidazole added. The eluant included imida-



zole which is cytotoxic, and thus the buffer was replaced with PBS using gel chromatography (PD-10 column, Amersham Pharmacia Biotech). The resultant purified protein was subjected to electrophoresis using SDS-PAGE and silver-stained to confirm the degree of purification.

(Example 2: Separation of CD34<sup>-</sup> KSL cells using FACS)

It is known that with respect to hematopoietic cells in bone marrow, hematopoietic stem cells with high purity can be separated by the use of separation of CD34 negative or weak negative, c-Kit positive, Sca-1 positive, differentiation antigen (Lin) negative cells (CD34<sup>-</sup> KSL cells) (Osawa, M. et al., Science, 273: 242-245, 1996). In this example, the following method using FACS was applied to separate CD34<sup>-</sup> KSL cells. The scheme therefor is shown in Figure 2.

(1. Preparation of bone marrow cell suspension)

The femur and tibia were removed from the lower thigh of B6 mice of about eight to ten weeks age. The muscle and fat tissues and the like were removed to separate bone only. Both ends of a tubular bone was subjected to resection and a syringe with a needle connected thereto was used to inject PBS (phosphate buffered saline) from one of the ends to obtain the contents of the bone (bone marrow). The bone marrow was suspended in PBS (phosphate buffered saline) and passed through a nylon filter (70  $\mu$ m) to remove cell aggregates and tissues such as contaminated muscles. The cell number in the cell suspension, which was filtered by the nylon filter, was counted (usually,  $4-5 \times 10^7$  cells were ob-



tained), and the cell concentration was controlled to about  $1 \times 10^7$  cells/ml by adding PBS. About 5 ml of the cell suspension was overlayed to 5ml Ficoll (Lymphoprep, Nycomed (Oslo, Norway)), centrifuged at room temperature, 400xg for 20 minutes to remove erythrocytes and neutrophils. After centrifugation, cells in the boundary surface were collected and washed twice with staining medium (SM; PBS containing 5% bovine fetal serum and 0.05 %  $\text{NaN}_3$ ) and the cell number was counted. Usually, about half of the cells before the centrifugation were recovered.

Biotinylated lineage antibodies (0.01-0.1  $\mu\text{g/ml}$  of anti-Mac-1 antibody(clone: M1/70) as a final concentration, 0.01-0.1  $\mu\text{g/ml}$  of anti Gr-1 antibody (clone: RB6-8C5) as a final concentration, 0.01 - 0.1  $\mu\text{g/ml}$  of anti B220 antibody (clone: RA3-6B2) as a final concentration, 0.01 - 0.1  $\mu\text{g/ml}$  of anti CD4 antibody (clone: RM4-5) as a final concentration, 0.01 - 0.1  $\mu\text{g/ml}$  of anti CD8 antibody (clone: 53-6.7) as a final concentration, 0.01 - 0.1  $\mu\text{g/ml}$  of anti erythrocyte antibody (clone: anti erythrocyte antibody TER 119); all available from Pharmingen (San Diego, USA)) were added to a cell suspension of about  $1 - 10 \times 10^7$  cell/ml of the cells and the suspension was subjected to reaction on ice for thirty minutes. The suspension was washed twice with SM, and was resuspended in 100  $\mu\text{l}$  of SM.

In order to purify the cells resuspended in the SM, Dynabeads were used and were pretreated as followed: streptavidin treated Dynabeads (Dynabeads M-280:Dynal; Oslo, Norway) were added so as the concentration thereof became 5-6 beads/cell, and washed with



SM using a magnetic stand. After washing, the Dynabeads were resuspended in 10 ml of SM.

5 The cells resuspended in SM and the pretreated Dynabeads were reacted on ice for thirty minutes. After the addition of 7 ml of SM, a magnetic stand was used to remove Linage positive cells (cells bound to biotinylated lineage antibodies) bound to Dynabeads from the cells were resuspended in SM, and the cell number was  
10 counted. Usually, about 5-10 % of the cells before removal remained.

After centrifugation (4 x, 400xg, five minutes), the following was added to the resultant cell pellets:

- 15 1) biotinylated lineage antibodies (in the amount of 5-10 % as the amount in which it was used for the first time)
- 2) 0.01-0.1 µg/ml of phycoerythrin (PE) labeled anti-Sca-1 antibody (clone: E13-161.7) as a  
20 final concentration;
- 3) 0.01-0.1 µg/ml of allophycocyanin (APC) labeled anti c-Kit antibody (clone: ACK2 or 2B8) as a final concentration;
- 4) 0.01-0.1 µg/ml of fluorescein isothiocyanate  
25 (FITC) labeled anti CD34 antibody (clone: RAM34 antibody) as a final concentration;

(2) to (4) were added simultaneously.

30 After incubation for about thirty minutes on ice, cells were washed and 0.01-0.1 mg/ml of streptavidin - Texas Red was added. After incubation for about thirty minutes on ice, the cells were washed and the cell con-



centration of the cell suspension was adjusted to about  $5 \times 10^5$  cells/ml using SM.

5 FACS Vantage (Becton Dickinson) was used for analysis. Lineage antigen negative cells were selected for Texas Red as indicator thereof (Figure 3A), and then KSL cells were selected by developing with Sca-1 and c-Kit for APC and PE as indicators thereof (Figures 3B), and then less than 10 % of CD negative or CD34  
10 weak negative cells were selected for FITC as an indicator (Figure 3C).

Selected CD34<sup>-</sup>KSL cells were sorted and used as hematopoietic stem cells.

15

(Example 3: Human hematopoietic stem cell preparation)

In principle, human hematopoietic stem cells can also be prepared using the same protocols as those used  
20 for mice. Accordingly, hematopoietic stem cells can be also separated from the equivalent of anti-Sca-1 antibodies for human as described above.

In Example 3, different experimental methods have  
25 been used for demonstrating the utility of the present invention. In human, heterogenous bone marrow transplantation system such as NOD/SCID mice, sheep or the like have to be used for hematopoietic stem cell assays. Human hematopoietic stem cells detected using this  
30 method are considered to be substantially equal to the mouse hematopoietic stem cells assayed using the systems of homogenous bone marrow transplantation system. Thus, such a system was used for the demonstration of



the present invention. The following is another method for separation of human hematopoietic stem cells.

1) After obtaining informed consent, bone marrow  
5 cells or umbilical cord blood, which can be obtained at delivery, from adults (from 18 years old to about 30 years old male and female) were collected in a heparinized syringe. The bone marrow solution or the umbilical cord blood was diluted three times with PBS.  
10 About 35ml of the cell suspension was overlaid onto about 15ml of Ficoll (Lymphoprep, Nycomed; Oslo, Norway) and centrifuged for thirty minutes at room temperature at 400xg to remove erythrocytes and neutrophils. After centrifugation, cells in the boundary surface  
15 were collected and washed twice with SM and the cell number was counted.

2) Biotinylated lineage antibodies (0.01-0.1  $\mu\text{g/ml}$  of anti-CD2, anti-CD7, anti-CD14, anti-CD16,  
20 anti-CD19, anti-CD24, anti-CD56, anti-CD66b and anti-Glycophorin A antibodies, respectively, as a final concentration) were added to a cell suspension of about  $1 - 10 \times 10^7$  cell/ml of the cells and the suspension was subjected to reaction on ice for thirty minutes. The  
25 suspension was washed twice with SM, and was resuspended in SM.

3) As in the mouse example, magnetic beads were used to remove lineage marker positive cells. After  
30 centrifugation, staining was conducted with 0.01 - 0.1  $\mu\text{g/ml}$  of fluorescein isothiocyanate (FITC) labeled anti-human CD34 antibody (Becon Dickinson) as a final concentration, 0.01 - 0.1  $\mu\text{g/ml}$  of PE labeled anti-



human c-Kit antibody as a final concentration, 0.01 - 0.1 µg/ml of APC labeled anti-human CD34 antibody (Beckton Dickinson) as a final concentration. Further, lineage antibodies were again used for restaining.

5

4) After incubation for about thirty minutes on ice, the cells were washed and 0.01-0.1 mg/ml of streptavidin-Texas Red was added thereto. After the incubation for about thirty minutes on ice, the cells were washed and the cell concentration of the cell suspension was adjusted to  $5 \times 10^5$  cells/ml using SM.

FACS Vantage (Becton Dickinson) was used for analysis. Lineage antigen negative and CD negative fractions were selectively developed with CD34 and c-Kit. Human hematopoietic stem cells are mainly concentrated in the CD34+Kit+ fractions, however, it recently became apparent that CD34- fractions also include such stem cells as in mouse. Therefore, two kinds, which are CD34+CD38-KL cells and CD34-CD38-KL cells, are subjected to sorting.

(Example 4: Effect of WIF-1 on expansion and differentiation of hematopoietic stem cells)

In order to study the effects of a variety of proteins on expansion and differentiation of hematopoietic stem cells, CD34- KSL cells were used as hematopoietic stem cells, and the expansion (capability of cell division as an indicator thereof) and differentiation (capability of colony formation consisting of matured blood cells as an indicator thereof) were studied.

(1. Method for measuring capabilities of cell di-



vision and colony formation of single CD34<sup>+</sup> KSL cells)

Round bottom 96-well plates (Corning Inc., New York, USA) were used for culture. 200  $\mu$ l of Stem-Pro-34 SFM (Life Technologies ) containing  $5 \times 10^{-5}$ M 2-beta-mercapto ethanol and 2 mM L-glutamine were added to the wells. Added soluble agents were as follows: 1.0ng/ml WIF-1 (as prepared in Example 1), 100 ng/ml mouse SCF, 100 ng/ml human TPO, 10 ng/ml mouse IL-3, 100 ng/ml human IL-6 (PeproTech, London, England), 100 ng/ml human IL-11 (PeproTech, London, England), and 10 ng/ml human G-CSF. SCF, TPO, IL-3 and G-CSF were available from Kirin Brewery Co. Ltd. (Takasaki, Japan). The cells were cultured at 5 % CO<sub>2</sub>, humidified at 37 °C. Cell number per well was monitored until seven days after culture, and the colony formation was determined on day fourteen of culture.

In the presence of a variety of predetermined proteins, single cell culture was conducted for fourteen days, and cell which underwent at least one cell division, were used as cell-division positive cells. The cells, which underwent a colony formation composed of at least 500,000 cells, were used as a colony formation cell.

(2. The effects of recombinant WIF-1 proteins only on the division and colony formation of CD34<sup>+</sup>KSL cells)

It was studied whether or not WIF-1 alone induces cell division and/or colony formation of CD34<sup>+</sup>KSL cells.

It was known that SCF induces cell division of CD34<sup>+</sup>KSL cells to some extent but fails to induce colony formation thereof (Ema et al., J. Exp. Med. vol 192,



Number 9, November 6, 2000). Therefore, SCF was used as a control.

According to the method described above in 1., a number of proteins were added to study the effects of the SCF and WIF-1 on the capability of cell division and colony formation of a single CD34<sup>+</sup>KSL cell. The results thereof are shown in Table 1.



Table 1. The effects of WIF-1 on the capability of cell division and colony formation of the CD34<sup>+</sup>KSL cell

Agent(s)	Cell Division	Colony Formation
none	0/96	0/96
SCF	10/96(10.4%)	0/96
WIF-1	0/96	0/96
SCF+WIF-1	23/96(24.0%)	0/96

SCF: Stem cell factor

5

As shown in Table 1, WIF-1 alone did not divide the single CD34<sup>+</sup>KSL cell into more than one cell or form colonies. In combination with the SCF, the WIF-1 significantly increased the ratio of cells in which more than one cell existed after cell division (i.e. the ratio of cell division). However, even in the presence of SCF+WIF-1, no colony formation has been observed.

10

(2. The effects of WIF-1 protein on cell division and secondary colony formation of CD34<sup>+</sup>KSL cells in the case of combined with another protein)

15

In the case where the SCF and FL were combined, effects of the WIF-1 protein on the cell division of the CD34<sup>+</sup>KSL cells were studied and it was also studied whether or not colony forming cells remain in the divided cells after fourteen days of culture. In the case where a living colony forming cell was observed, it was determined to be secondary colony positive. The results thereof are shown in Table 2.

20



Table 2. The Effects of WIF-1 on cell division and secondary colony formation of the CD34<sup>+</sup>KSL cells in combination of the SCF and/or FL

Agent(s)	Cell Division	Secondary Colony Formation
SCF	5/48 (10.4%)	0/5
SCF+WIF-1	8/48 (16.7%)	5/7
SCF+FL	11/48 (22.9%)	8/9
SCF+WIF-1+FL	22/48 (45.8%)	8/8

5

SCF : Stem cell factor; FL :Flt-3 ligand

The results of Table 2 show that in combination with SCF, WIF-1 supports cell division of the CD34<sup>+</sup>KSL cells which are hematopoietic stem cells, and that immature cells having colony formation capability in the divided cells survived at least fourteen days of culture. Accordingly, it has become apparent that WIF-1 induces slight propagation of a hematopoietic stem cell in combination with SCF, the slightly divided cells do have surviving cells, and the surviving cells are not induced for differentiation. Further, it has become apparent that WIF-1 supports the survival of immature cells in a more potent manner when used in combination with SCF and FL.

20

(Example 5: The effects of WIF-1 for maintaining hematopoietic stem cells which can regenerate *in vivo*)

The isolated hematopoietic stem cells are regen-



erated into the hematopoietic system by the proliferation and differentiation capability thereof upon transplantation into the living organism. Therefore, CD34<sup>+</sup> KSL cell as an isolated hematopoietic stem cell was  
5 cultured and it was studied whether or not the cultured cells have the capability of regenerating the hematopoietic system in the body after the culture, i.e., maintaining hematopoietic stem cells after culture. WIF-1 was added to the culture solution, and the direct  
10 effects of WIF-1 on the maintenance of hematopoietic stem cells were studied.

In order to compare and quantitate the capabilities of propagation and differentiation of the hematopoietic stem cells, a competitive repopulation assay  
15 was used and the method thereof is described below.

(1. Competitive repopulating assay)

When hematopoietic stem cells are transplanted  
20 into mouse which received a fatal dose of radiation, recipient mouse hematopoietic system is reconstructed for a long period of time by the capability of self-regeneration and pluripotency of the hematopoietic stem cells. That is, by studying the long hematopoietic system repopulation capability, it is possible to deter-  
25 mine the presence or absence of hematopoietic stem cells in the cells transplanted into the body. The competitive repopulation assay refers to a method for simultaneously transplanting cells of interest (test  
30 cells) and a certain amount of bone marrow cells (competitor cells) into a mouse which has received radiation. This method enables the recipient mouse to survive without the presence of precursor cells required



for the survival of the recipient mouse for a shorter period of time, or without the presence of hematopoietic stem cells in the test cells which stem cells are required for longer survival of the recipient mouse.

- 5 The relative evaluation of the hematopoietic stem cell activity in the test cells can also be made. Specifically, the following experiments were conducted.

10 Ly5 congenic mouse was used for the competitive repopulation method (D. A. Ogden and H. S. Micklem, (1976) Transplantation. 22: 287-293; and D. E. Harrison et al., (1978) J. Exp. Med. 147: 1526-1531) to evaluate the prepared hematopoietic stem cells (H. Ema et al., (2000) Blood. 95: 2284-2288). In brief, CD34<sup>+</sup>KSL cells  
15 or CD34<sup>+</sup>KSL derived cells (B6-Ly5.1) in culture were mixed with  $2 \times 10^8$  bone marrow competitor cells (B6-F1) and cultured for a predetermined period of time and 200  $\mu$ l of the cell suspension containing 10 CD34<sup>+</sup>KSL cells were injected into the tail vein of B6-Ly5.2 mouse  
20 which received 9.5 Gy radiation (Figure 5).

After transplantation, the mouse was housed under circumstances of specific pathogen-free (SPF) for a certain period of time, and the mouse was anesthetized  
25 by ether inhalation and blood was taken from the orbital cavity vein to fill a 100  $\mu$ l capillary tube (as a preliminary, a small volume of 0.1 M EDTA  $\cdot$  Na<sub>2</sub>/H<sub>2</sub>O was taken using the capillary phenomenon). The taken blood was transferred to an Eppendorf tube and mixed well and  
30 centrifuged at 2,000 rpm for two seconds to remove the blood. 350  $\mu$ l of distilled water was added thereto and left to stand for thirty second at room temperature. 350  $\mu$ l of 2 x PBS was added thereto and after suffi-



cient agitation, it centrifuged at 2,000 rpm for two minutes. The supernatant including hemolyzed erythrocytes was discarded and the blood cell pellet was suspended in SM and divided into two portions which were  
5 subjected to centrifugation.

The resultant cell pellets were stained using two kinds of antibody stains, namely biotinylated Ly5.1(A20) antibody and FITC conjugated Ly5.2(104) antibody as described in Example 1. The cells were  
10 stained using PE conjugated B220 antibody, or PE conjugated anti-Mac-1 antibody, and PE conjugated anti-Gr-1 antibody or PE conjugated anti-CD4 antibody and PE conjugated anti-CD8 antibody, as described in Example 1.  
15 The biotinylated antibodies were developed using streptavidin-APC (Pharmingen, San Diego, USA). After incubation at 4°C for twenty minutes, the cells were washed and were resuspended in 200 µl of SM and analyzed using FACS. Ly5.1 and Ly5.2 were used for developing and  
20 cells derived from the test cells and competitor derived cells, as well as the remaining cells of the recipient were detected in a distinguishing manner. Further, the cells derived from the test cells were studied with respect to whether these were granulocytes,  
25 macrophages, B lymphocytes, and T lymphocytes.

The % chimerism was determined by using the following formula:

30 
$$\text{Total chimerism (\%)} = \% \text{ Ly5.1 cells} \times 100 / (\text{Ly5.1 cells} + \% \text{ F1 cells})$$

In the present formula, positive mice are defined



to be mice in which 1 & or more chimerism is shown in  
all of the granulocytes, macrophages, T lymphocytes,  
and B lymphocytes of the blood system; and negative  
mice are defined to be mice other than the positive  
5 mice.

(2. Effects of the WIF-1 on the maintenance of  
hematopoietic stem cells)

The SCF and WIF-1 are used to study the mainte-  
10 nance of hematopoietic stem cells using the method de-  
scribed above in 1. The results are shown in Table 3.



**Table 3: The maintenance of hematopoietic stem cells by WIF-1**

Agent(s)	Culture period	Period after trans-plantation	Number of positive mice	% chimerism (number of mice)
<b>First Round</b>				
none	0 days	12 weeks	3/3	10.1±7.2(3)
SCF	5 days	12 weeks	0/2	ND
SCF+WIF-1	5 days	12 weeks	8/10	34.3±17.7(8)
<b>Second Round</b>				
none	0 days	12 weeks	7/10	24.3±16.8(7)
SCF	5 days	12 weeks	0/10	ND
SCF+WIF-1	5 days	12 weeks	4/10	15.8±15.3(4)

ND: not detectable

5

As shown in Table 3, WIF-1 in combination with SCF, have lead to the maintenance of the hematopoietic stem cells during the culture period, which was not observed when SCF alone was used.

10

Next, TPO in combination with SCF (SCF+TPO) was compared with the combination of WIF-1 with SCF and TPO (SCF+TPO+WIF-1).

15

Further, as shown in Table 4, when no WIF-1 was added but SCF and TPO were added in combination to the CD34<sup>+</sup>KSL cells culture, no reproducible hematopoietic



stem cell maintenance was observed, whereas when WIF-1 was combined with SCF and TPO, the maintenance of hematopoietic stem cells was observed in a reproducible and highly reliable manner.

5

Table 4: The maintenance of hematopoietic stem cells by WIF-1

Agent(s)	Culture period	Period after transplantation	Number of positive mice	% chimerism (number of mice)
First Round				
none	0 days	24 weeks	6/10	5.6±5.2(6)
SCF+TPO	3 days	24 weeks	3/10	7.0±6.1(3)
SCF+TPO+WIF-1	3 days	24 weeks	6/10	14.8±11.6(6)
Second Round				
none	0 days	12 weeks	3/3	10.1±7.2(3)
SCF+TPO	6 days	12 weeks	0/10	ND
SCF+TPO+WIF-1	6 days	12 weeks	10/10	15.0±15.0(10)

ND: not detectable

10

(Example 6: Gene introduction into a stem cell in the presence of WIF-1)

After the separation of CD34-KSL cells from mouse bone marrow cells, GFP (Green Fluorescence Protein) was introduced to 300 to 600 cells of CD34-KSL cells as a marker gene in the presence or absence of the WIF-1,

15



and the resultant cells were transplanted into five mice which received radiation treatment.

Preparation of retrovirus: 293T cell lines and the Packaging Cell lines PG13, 293GP and 283 GPg were cultured in a DMEM supplemented with 10 % FCS. pGCSa-pEGFP (a retrovirus vector provided by Dr. Masafumi ONODERA at Tsukuba University) was transfected into 293 GP cells using the phosphate calcium method. The culture supernatant comprising the resultant viral particles was collected and infected into the PG13 cells. Further, the culture supernatant of the PG13 cell line was used to infect 293GPg cells (tetracyclin susceptible expression induction system: tet-off). Culture supernatant obtained by switching into Tet off was centrifuged at 6,000 x g for sixteen hours, and the resultant viral particles were resuspended in Stem-Pro34 serum-free culture media.

Preparation of lentivirus: pCS-CG-PRE(a SIN vector in which a woodchuck posttranscriptional regulatory element was inserted downstream of the GFP), pMDLg/pPRE(packaging construct), pRSV-Rev (Rev-expressing construct), pMD.G(VSV-G-expressing construct) were available by Dr. Hiroyuki MIYOSHI at Tsukuba University. These plasmids were transfected into the 293T cell line simultaneously using the calcium phosphate method. Culture supernatant was collected and ultracentrifuged to obtain a viral particle concentrate which was used for infection experiments.

In the presence of 100 ng/ml SCF and 100 ng/ml TPO, D34-KSL cells were cultured in the absence of se-



rum in 96-well plates which wells were coated with vitronectin (TaKaRa) as a control. Further, under the same conditions, 1 ng/ml of WIF-1 was added to additional cultures (pre-incubation). Retroviral particle concentrates were added to the culture with 5 µg/ml protamine sulfate (Sigma, St. Louis, USA) after 24 hours of culture. After 48 hours, the resultant culture cells were transplanted into mice which had received radiation treatment (competitive hematopoietic system repopulation assay).

In the presence of 100 ng/ml SCF and 100 ng/ml FL, D34-KSL cells were cultured in the absence of serum in a 96-well plates which wells were coated with vitronectin (TaKaRa) as a control. Further, under the same conditions, 1 ng/ml of WIF-1 was added to additional cultures (pre-incubation). Lentivirus particle concentrates were added to the culture with 5 µg/ml protamine sulfate (Sigma, St. Louis, USA) at the beginning of culture. Within 24 hours, the resultant culture cells were transplanted into mice which had received radiation treatment (competitive hematopoietic system repopulation assay).

Repopulation by the cultured cells three months post-transplantation and the gene introduction efficiency into the repopulated blood cells were evaluated. As a result, it became apparent that the group which received the WIF-1 at the time of viral infection had a significantly higher gene introduction rate than the others.

(Example 7: Large scale production of mouse and



human WIF-1 recombinant proteins)

In order to study the effects of WIF-1 *in vivo*, it is necessary to produce a large amount of purified protein. Accordingly, cells stably producing mouse and  
5 human WIF-1 recombinant proteins were established. Mouse or human cDNA were inserted into the pcDNA 3.1 expression vector (Invitrogen, Groningen, The Netherlands) (pcDNA3.1/mWIF-1, pcDNA3.1/hWIF-1).  
10 pcDNA3.1/mWIF-1 and pcDNA3.1/hWIF-1 were transduced into CHO cell lines using calcium phosphate method, and the cells were cultured using DMEM (Dulbecco's Modified Eagle Medium) supplemented with 10 % FCS in the presence of 5% CO<sub>2</sub> at 37°C.

15 Thereafter, a drug resistant cell was obtained by culturing in the presence of Zeosin (Invitrogen, Groningen, The Netherlands). Then a single cell was sorted using FACS. Cell lines were thus cloned. Then the Western blotting method was used to select clones which  
20 express WIF recombinant proteins highly.

Clones with high expression were cultured in DMEM (Dulbecco's Modified Eagle Medium) supplemented with 10% FCS in the presence of 5% CO<sub>2</sub> at 37°C to produce  
25 mouse and human WIF-1 recombinant proteins in a large amount.

(Example 8: The effect of conservatively substituted variants of WIF-1)

30 In the sequence set forth in SEQ ID NO: 2, variants were made by site directed mutagenesis in which the amino acid number 55 isoleucine was substituted with leucine, the amino acid number 109 leucine was



substituted with isoleucine, the amino acid number 244 alanine was substituted with valine, the amino acid number 271 glutamic acid was substituted with aspartic acid (SEQ ID Nos: 15, 17, 19 and 21, respectively). In the site directed mutagenesis, the Quick Change™ kit (Stratagene) was used according to the manual of the manufacturer. In brief, the following was conducted.

1. Double-stranded plasmid DNA was heat denatured and two kinds of primer having mutations introduced therein were annealed to the same base sequence site of the respective complementary DNA strands.
2. The Pfu Turbo DNA Polymerase was used to elongate the primers using the temperature cycling method (Cycling number: 10-16) to synthesize circular DNA strands with nicks introduced therein having the mutation.
3. Dpn I was used to degrade the template DNA. DNA prepared from an *E. coli* cell line which does not require dam methylase, has methylated, and was degraded by Dpn I which is specific to methylated and hemimethylated DNAs (5'-G<sup>m</sup>ATC-3'). On the other hand, DNA with the mutation introduced therein is not degraded.
4. An *E. coli* was transformed with the DNA having the nicked mutation. The nick in the plasmid having the mutation was recovered in the *E. coli*.



Four variants (the nucleotide sequences were set forth in SEQ ID NOs: 14, 16, 18 and 20) were prepared by the above-described method and used for the following experiments.

(The effect of WIF-1 variants against hematopoietic stem cells)

The experiments were conducted as described in Examples 4 and 5, and the effects on the propagation and differentiation of hematopoietic stem cells and the maintenance of the hematopoietic stem cells transplanted in vivo, were confirmed.

As for the wild-type sequences, in combination with SCF, the WIF-1 variants showed induction of both cell division and colony formation of CD34<sup>+</sup>KSL cells which are hematopoietic stem cells. Accordingly, the WIF-1 variants were demonstrated to have induced both cell proliferation and differentiation of hematopoietic stem cells when combined with SCF. Further, the WIF-1 variants were demonstrated to have augmented the effects of FL which is another factor to induce both proliferation and differentiation of hematopoietic stem cells.

The WIF-1 variants, when combined with SCF, have led to the maintenance of the transplanted hematopoietic cells, which was not observed in the case where only SCF is used.

The above-identified four kinds of variants showed the maintenance of hematopoietic stem cells in a



reproducible manner and in a high probability when combined with SCF and TPO.

Accordingly, it was demonstrated that the conservatively substituted variants showed effects attained by the present invention in a manner similar to the wild-type sequences.

(Example 9: The importance of domains)

Next, a variant in which the WIF domain was left, and the other regions were deleted and a variant in which the EGF-like repeat was left and the other regions were deleted, were prepared. Specifically, a variant in which a 6His-Tag was added to the first amino acid numbers 1 to 176 of SEQ ID NO: 2 (the nucleotide sequence thereof is shown in SEQ ID NO: 22, and the amino acid sequence thereof is shown in SEQ ID NO: 23), and a variant in which signal sequence (amino acid numbers 1 to 24) and the EGF-like repeat (amino acid numbers 177 to 379) were fused and a 6His-tag was added (the nucleotide sequence thereof is shown in SEQ ID NO: 24, and the amino acid sequence thereof is shown in SEQ ID NO: 25), were prepared in accordance with well known technologies.

25

(The importance of domains on hematopoietic stem cells)

Experiments were conducted as described in Examples 4 and 5 to confirm the effects on propagation and differentiation of hematopoietic stem cells, and the maintenance of hematopoietic stem cells transplanted *in vivo*.

30



As for the wild type sequences, in combination with SCF, the WIF-1 variants showed induction of both cell division and colony formation of CD34<sup>+</sup>KSL cells which are hematopoietic stem cells. Accordingly, the  
5 WIF-1 variants were demonstrated to have induced both cell proliferation and differentiation of hematopoietic stem cells when combined with SCF. Further, the WIF-1 variants were demonstrated to have augmented the effects of PL which is another factor to induce both pro-  
10 liferation and differentiation of hematopoietic stem cells.

The WIF-1 variants, when combined with SCF, have led to the maintenance of the transplanted hematopoi-  
15 etic cells, which were not observed in the case where only SCF is used.

The above-identified variants showed the maintenance of hematopoietic stem cells in a reproducible  
20 manner and in a high probability when combined with SCF and TPO.

The variant having only the WIF domain, and that having only the EGF-like repeat, have been shown to  
25 have reduced effects compared to the wild-type sequences. Accordingly, therefore it is understood that both domains should be included in practicing the present invention.

30 Accordingly, it was demonstrated that the conservatively substituted variants showed the effects to be attained by the present invention in a similar manner to the wild-type sequences.



## INDUSTRIAL APPLICABILITY

The present invention attained the maintenance of the pluripotency of stem cells while maintaining the undifferentiated state thereof. This enabled the easy provision of stem cells (for example, hematopoietic stem cells) in a large amount. In addition, the stem cell composition of the present invention is homogeneous and impurities therein are significantly reduced. Therefore, the present invention is shown to have significantly improved side effects such as infection, rejection response and the like which haven been problematic in conventional treatments using hematopoietic stem cells. Further, it was shown that the present invention can be applied to effective gene therapies. These can be recognized to be significant effects. Further, compositions, cells, kits, medicaments and the like used for the treatment methods of the present invention have sufficient industrial applicability. The present invention is considered to have sufficient industrially applicability and utilities since for example, pharmaceutical industries except for medical doctors can produce the composition of the present invention as an industry. The present invention *per se* also has industrial applicability since it is useful for clinical trials *per se* which are of industrial purpose *per se*, in addition to medical treatment methods which are for pure medical purposes. Further, the indirect and direct workings of the methods of the present invention are considered to have the possibility of use in industries in the vicinity of medical industry, there is/are sufficient industrial applicability or utilities.